ACS

Color 320 x 240 LCD

Display Terminal

Quick Start Guide

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ACS
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Getting Started

The ACS Color 320x240 LCD Display Terminal is both easy to use and very powerful. This guide will attempt to get you up and running quickly.

What you Need

To get started you need the following items:

1. ACS Color 320x240 LCD Display Terminal powered by one of the three Supplying Power options.
2. Host Personal Computer (PC) with an available communications port compatible with one of the three Providing Communication options.
3. Software installed on the PC to provide Terminal Emulation.
4. Windows driver for the PC if a USB connection to the display is used.

In the following pages of this guide we will further examine each of these items and how they are used together to get started with the Color LCD.

Supplying Power

The display requires a source of power to operate. There are three ways to power the display:

1. Using a couple of pins on the SERIAL connector to connect an external power supply.
2. Using a USB connection to supply power.
3. Using the optional Power Over Ethernet (POE) module and an external Ethernet power injection module.

WARNING: Do not install the USB_POWER jumper if powering the display through the SERIAL connector or external Ethernet power injection module. High voltage will be injected back through your USB cable to the host computer.

Let's look at each of these options in more detail.

Via SERIAL Connector with ACS Power Injector

This consists of a back-to-back pair of DB-9 serial connectors with a wall transformer. The Color LCD can be powered through two pins on its SERIAL connector. This injector supplies that power while allowing the other serial connector pins to pass through to your application cabling and hardware.

ACS LCD Power Injector

Via USB DEVICE Connector with USB Cable

This consists of a USB A to Micro B cable that connects the Color LCD's DEVICE connector to your PC. The USB_POWER jumper by the USB DEVICE connector must be installed.

WARNING: Do not install the USB_POWER jumper if powering the display through the SERIAL connector or external Ethernet power injection module. High voltage will be injected back through your USB cable to the host computer.

USB A to Micro B Cable

Via ETHERNET Connector with Power Over Ethernet

This requires the optional POE module be installed on the Color LCD and an IEEE802.3af Ethernet power injector cabled to the ETHERNET jack on the display. The power injector is placed in series between the host PC or network switch and the display.

PWR128RA 19W Power Over Ethernet Injector

The connection supports Power Over Ethernet (POE) if the optional POE module is installed on the controller and can be used to power the display with remote power injection. The POE support is IEEE802.af compliant and provides a Class 0 signature. Both DC power on Spares (mode B) and DC power on Data (mode A) operation is supported:

ETHERNET Pin #	POE DC Power on Spares		POE DC on Data	
	MDI Signal	MDIX Signal	MDI Signal	MDIX Signal
1	TX+	RX+	TX+ PSE+	RX+ PSE+
2	TX-	RX-	TX- PSE+	RX- PSE+
3	RX+	TX+	RX+ PSE-	TX+ PSE-
4	PSE+	PSE+		
5	PSE+	PSE+		
6	RX-	TX-	RX- PSE-	TX- PSE-
7	PSE-	PSE-		
8	PSE-	PSE-		

Providing Communication

The display can run without any other connections however most applications will require some form of communications between the display and an external device.

There are three communication connections: EIA Serial, USB and Ethernet.

1. Using the **SERIAL** connector to connect to your PC or other communications source. The connection may be either full duplex RS-232 configurable as DCE or DTE with hardware flow control, or half duplex RS-485.
2. Using the USB **DEVICE** connector to connect to your PC or other communications source. The connection emulates a virtual serial port by implementing a Communications Device Class.
3. Using the **ETHERNET** connector to connect to your PC network or other communications source. The connection provides a 10Base-T/100Base-T with auto negotiation and auto MDI/MDI-X detection and correction.

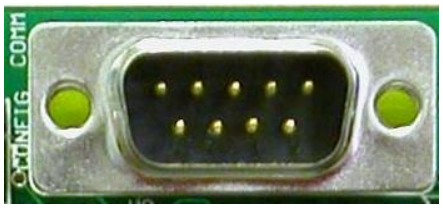
Let's look at each of these options in more detail:

SERIAL Connector

The display can function as either a RS-232 DTE (Data Terminal Equipment) or RS-232 DCE (Data Communications Equipment) device. There is a jumper block site on the controller labeled JB1 that can be used to reverse the pins of the signals pairs TxD, RxD and RTS, CTS on the SERIAL connector to accomplish this change.

DB-9P Signals

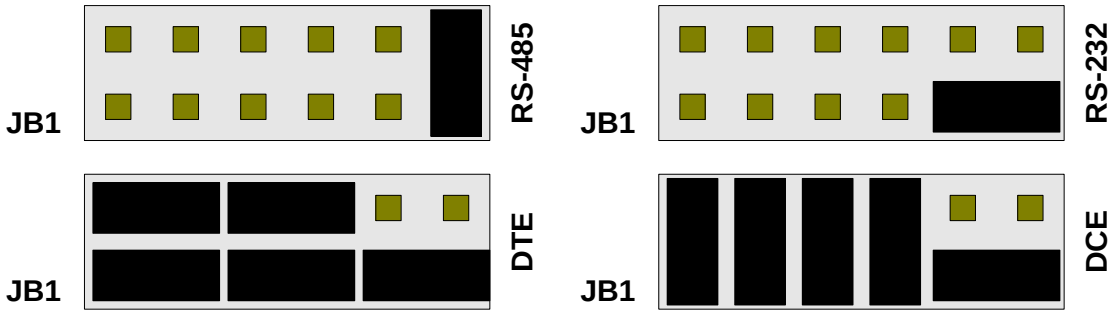
Connection to the SERIAL connector requires a female DB-9S mating connector. The following signals appear on the male SERIAL DB-9P connector:



SERIAL DB-9P Connector

PIN	DCE Signal	JB1 as DCE Direction		DTE Signal	JB1 as DTE Direction
1	RS-485 B-	I/O		RS-485 B-	I/O
2	RS-232 TxD	OUT		RS-232 RxD	IN
3	RS-232 RxD	IN		RS-232 TxD	OUT
4					
5	GND	PWR		GND	PWR
6	RS-485 A+	I/O		RS-485 A+	I/O
7	RS-232 CTS	IN		RS-232 RTS	OUT
8	RS-232 RTS	OUT		RS-232 CTS	IN
9	+12-15VDC	PWR		+12-15VDC	PWR

JB1 Configuration Jumpers



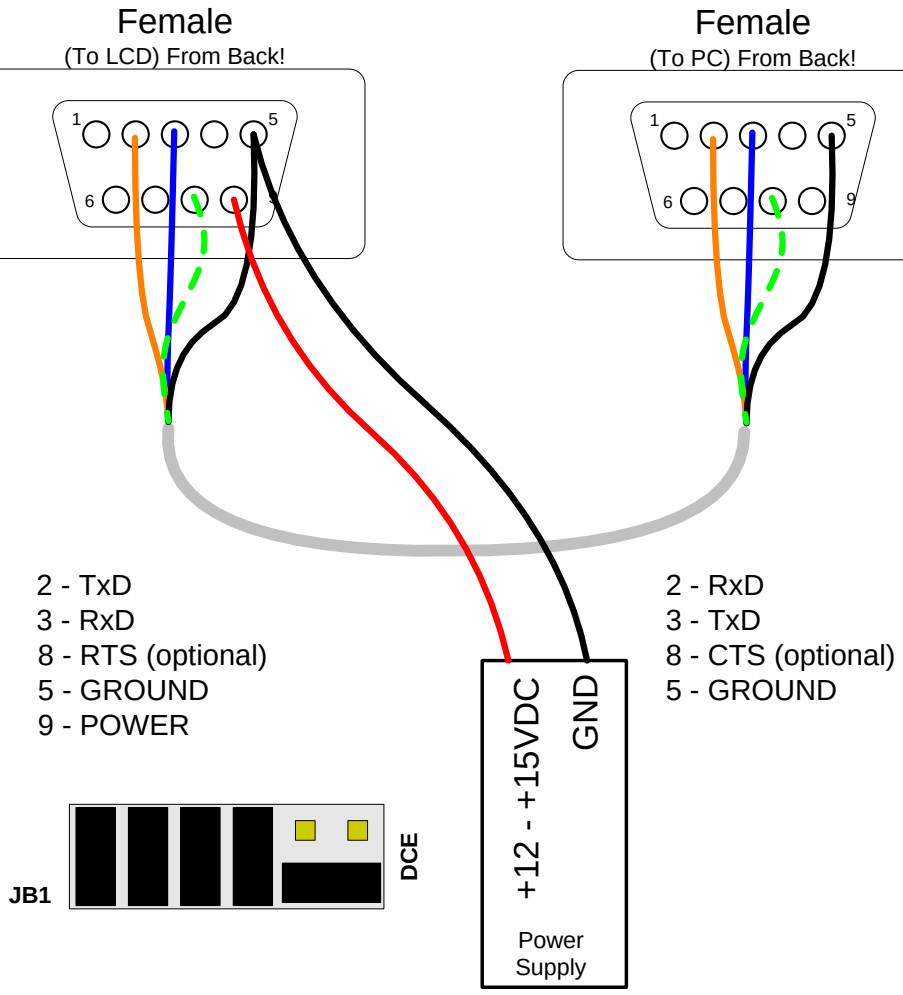
RS-232 Connection to PC

The PC is configured as a DTE device. A one-to-one, female DB-9S to DB-9S cable can be used to connect the PC communication port to the Color LCD SERIAL connector when the Color LCD is configured as DCE. Only four wired connections are required.

The RTS connection is for optional flow control of the transmit data to the display to prevent over-flowing the display input buffer at higher baud rates. It requires disabling the RS-485 enable in the display configuration and implementation of flow control on the host device supplying the data to the display.

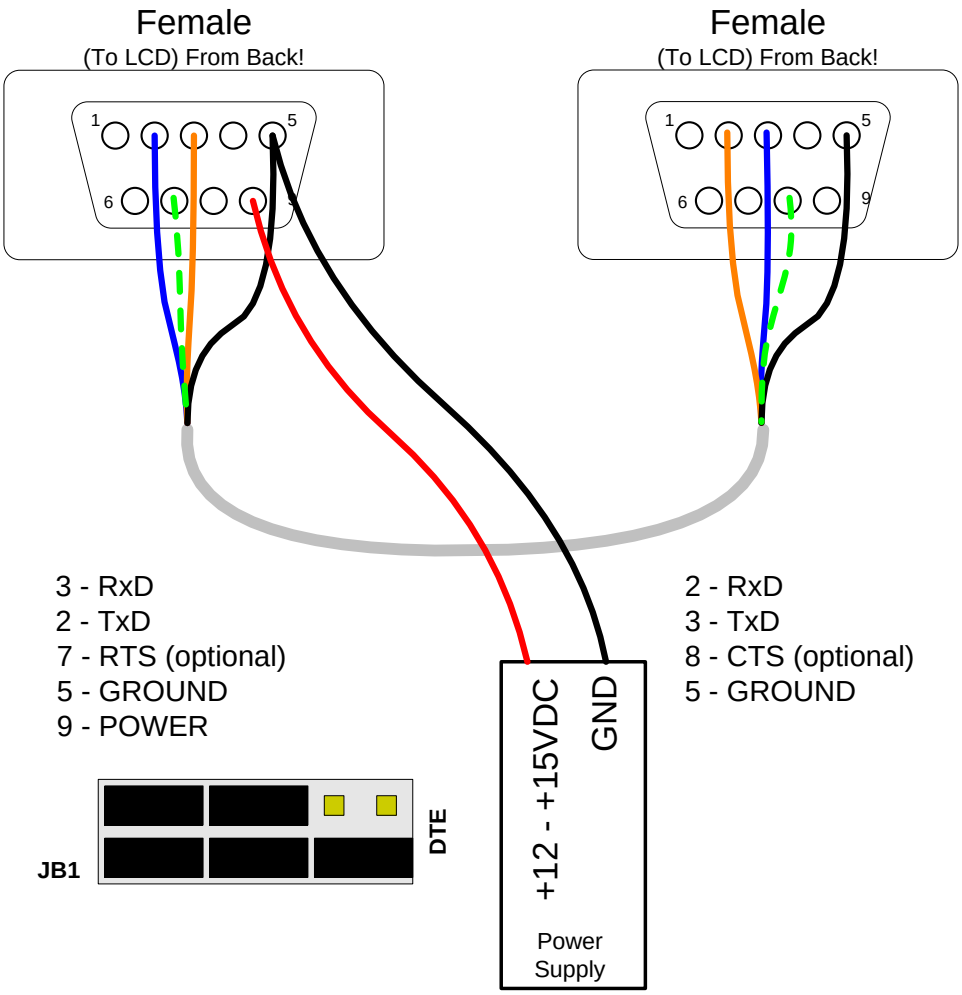
RS-232 LCD (JB1 jumpered as DCE) to PC (DTE)

The Color LCD can be connected with a one-to-one cable between the display and host PC when JB1 is configured for DCE:



RS-232 LCD (JB1 jumpered as DTE) to PC (DTE)

The Color LCD can be connected with a null modem cable (or one-to-one cable with null modem adaptor) between the display and host PC when JB1 is configured for DTE:



RS-485 Connection

The LCD display can be used with RS-485 serial connections. The RS-485 Enable configuration item must be turned on to control when the driver is enabled on the bus:

SERIAL Pin #	Power Supply	LCD SIGNAL
6		A+
1		B-
5	GND	GND
9	+12 → +15VDC	+12 → +15VDC

NOTE: Be sure to connect both the Ground of the PC or Host computer and the Ground of your +12 → +15VDC Power supply together!

The RS-485 A+ and B- signals are terminated with a 100 ohm resistor between them. In addition, there is a 10K pull-up resistor on the A+ signal to +3.3v and a 10K pull-down resistor on the B- signal to Ground, to put the received data line in an idle state when there is no connection.

USB Connector

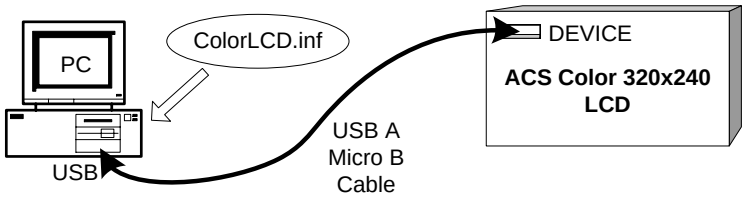
The LCD display can be connected as a USB serial communications device. A Micro B USB DEVICE connector is provided and the display can be connected to a PC with a USB A to Micro B cable.

DEVICE Pin #	Signal Name	Description
1	VBUS	USB Power +4.5v
2	D-	Data -
3	D+	Data +
4	ID	Identification (nc)
5	GND	Ground

A ColorLCD.inf file is available that identifies the Color LCD as a virtual serial port device that implements the Communications Device Class. (A Linux USB CDC configuration file is also available)

WARNING: Do not install the USB_POWER jumper if powering the display through the SERIAL connector or external Ethernet power injection module. High voltage will be injected back through your USB cable to the host computer.

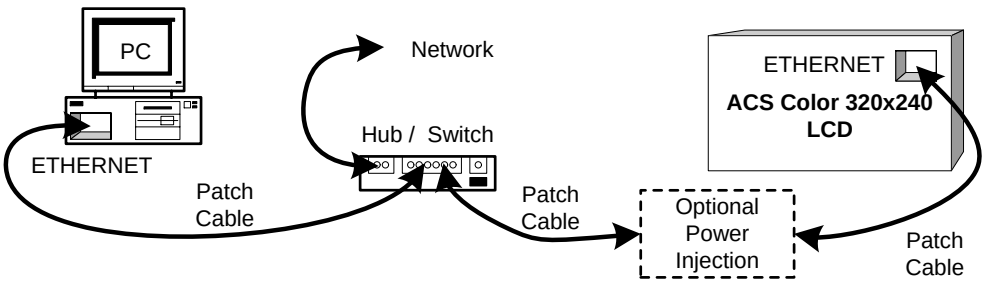
Connect the **USB A to Micro B cable** to the Color LCD **DEVICE** connector. Connect the other end of the cable into a USB port on your PC.



Windows will indicate that it has found new hardware and will eventually prompt for the location of a driver for the Color LCD. Browse to the location of the ColorLCD.inf file that you have downloaded and select it. Windows should now finish installing the new hardware and it should be ready to use. The COM port identifier that Windows will assign to the Color LCD will depend upon what other communications devices are present in the system and can be determined using the Device Manager.

Ethernet Connector

The LCD display can be connected as an Ethernet device. A standard RJ-45 connector is provided and it can be connected to a network with a standard Ethernet cable – either straight or crossover, detection and correction is automatic via HP Auto MDI/MDI-X configuration. The network speed can be either 10 or 100 mbps with auto link negotiation. A link activity indicator is provided on the ETHERNET jack.



The LCD display supports a configurable MAC address and configurable static IP address and IP mask. Serial communication is performed using TCP/IP Raw Sockets with configurable MAC, IP and port addresses.

How the Communication Works

The RS-232 SERIAL connection is essentially always connected – even if no physical connection is present.

The USB connection is 'connected' when the cable is plugged into a host PC where the driver has been installed.

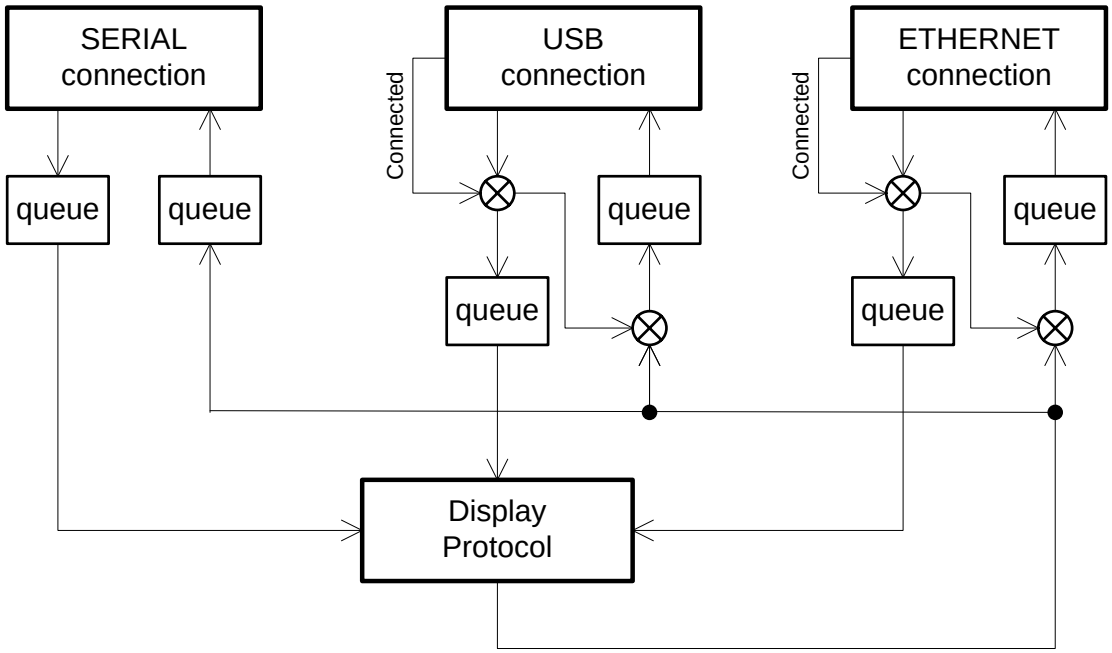
The ETHERNET connection is 'connected' when the display has been connected to the network and a TCP/IP raw sockets link has been established.

Incoming data from each of the three sources are combined asynchronously in parallel into the display protocol that is running.

Any output that the display protocol generates is copied to all three outputs synchronously. If a connected output queue fills up, the other outputs are delayed until the full queue has space available - so the slowest connected output limits the output data rate to all of the outputs.

Note that some USB hosts like Windows will stop responding to the USB connection if it is connected and there is no application running to receive the incoming data – stopping the output data to all of the outputs.

Here's a diagram:



Terminal Emulators

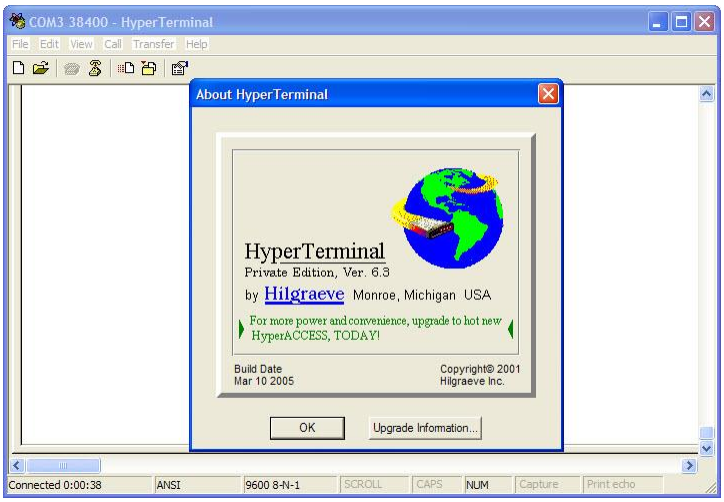
Communication with the Color LCD display connected to the Host PC requires a software program that can send PC keyboard key presses as characters to the connected display and display characters from the connected display on the PC screen. These programs are collectively, commonly referred to as Terminal Emulators since they emulate the function of older, dumb ANSI terminals that had a dedicated keyboard and display. The display is emulated on the PC screen, typically in a window. The dedicated keyboard is emulated using the PC keyboard. The ANSI character functions are translated in both directions to emulate the terminal operation.

Depending upon your LCD application, you may not have a PC in the solution or require communication to one so your software requirement may be different. For the purposes of this Quick Start Guide the use of a PC and terminal emulator program is required.

There are several software emulator programs – here are a few that have been tried and are known to work.

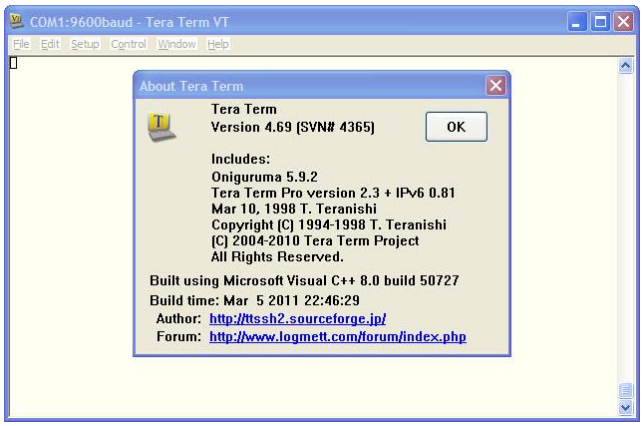
Hyperterminal

Windows 95, 98 and XP shipped with a terminal emulator known as Hyperterminal. Unfortunately this program is no longer supplied with the newer versions of Windows. Here's a link: http://www.hilgraeve.com/hyperterminal-trial/



Tera Term

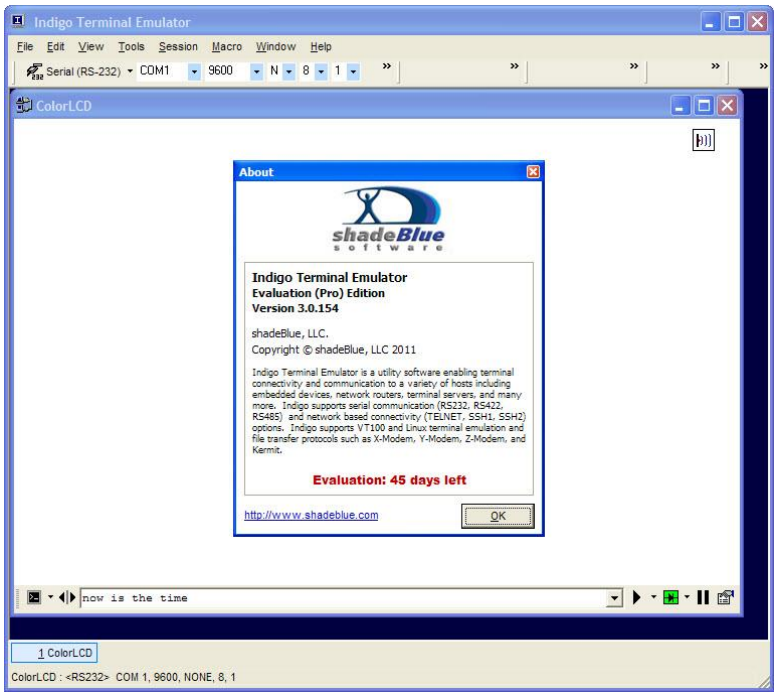
This is a freeware terminal emulator that is mature and still being developed. Source code is available. The program can be searched for on Google – here's a link: http://logmett.com/index.php?/download/tera-term-475-freeware.html


COM1:9600baud - Tera Term VT
File Edit Setup Control Window Help
About Tera Term
Tera Term
Version 4.69 (SVN# 4365)
OK
Includes:
Oniguruma 5.9.2
Tera Term Pro version 2.3 + IPv6 0.81
Mar 10, 1998 T. Teranishi
Copyright (C) 1994-1998 T. Teranishi
(C) 2004-2010 Tera Term Project
All Rights Reserved.
Built using Microsoft Visual C++ 8.0 build 50727
Build time: Mar 5 2011 22:46:29
Author: http://ttssh2.sourceforge.jp/
Forum: http://www.logmett.com/forum/index.php

shadeBlue Indigo Terminal Emulator

This is a commercial terminal emulator that is available for purchase online – here's a link: http://www.shadeblue.com/indigo-features

This emulator is initially more difficult to setup, but is very powerful and has some nice display, command and macro capabilities.

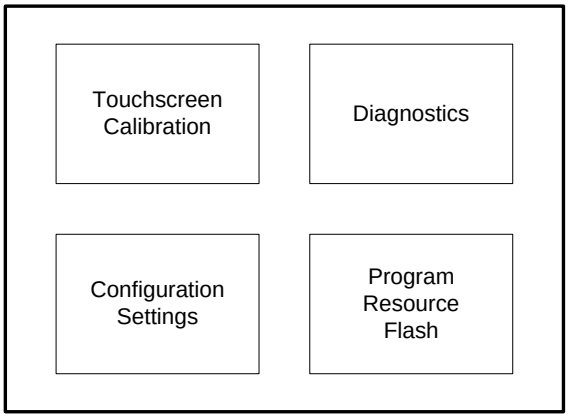

Indigo Terminal Emulator
File Edit View Tools Session Macro Window Help
Serial (RS-232) COM1 9600 N 8 1
ColorLCD
About
shadeBlue software
Indigo Terminal Emulator
Evaluation (Pro) Edition
Version 3.0.154
shadeBlue, LLC.
Copyright © shadeBlue, LLC 2011
Indigo Terminal Emulator is a utility software enabling terminal connectivity and communication to a variety of hosts including embedded devices, network routers, terminal servers, and many more. Indigo supports serial communication (RS232, RS422, RS485) and network based connectivity (TELNET, SSH1, SSH2) options. Indigo supports VT100 and Linux terminal emulation and file transfer protocols such as X-Modem, Y-Modem, Z-Modem, and Kermit.
Evaluation: 45 days left
http://www.shadeblue.com
OK
now is the time
1 ColorLCD
ColorLCD : <RS232> COM 1, 9600, NONE, 8, 1

Initial Power-up

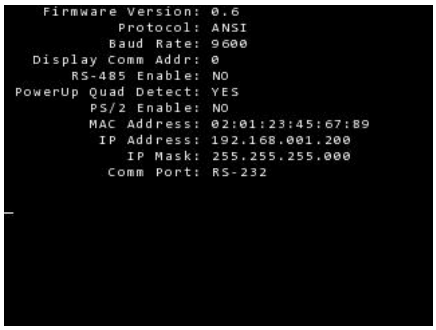
Use one of the previously described power connections to provide power to the Color LCD display. The display should power-up and present some diagnostic and configuration information.

Find and press the RESET button on the back of the display. Notice that the display again goes through the power-up sequence.

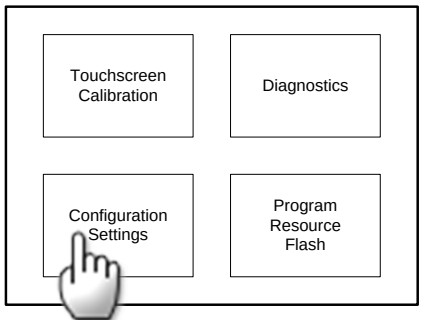
Now we need to configure the display settings for proper operation in your application. When power is applied or the ACS Color LCD 320x240 Display is reset, the controller initializes the display, turns on the backlight, then initializes the non-volatile memory, keypad, serial communications and touch screen. Next, if the touch screen reports that it has a continuous touch, the coordinate of the touch location is used to force the display into one of four startup modes depending upon which quadrant is being touched:



If there is no touch held in any quadrant, the display finishes powering up:



Since we have to configure the display settings we need to enter the configuration mode. Press the RESET button and hold your finger on the lower left quadrant of the touchscreen:

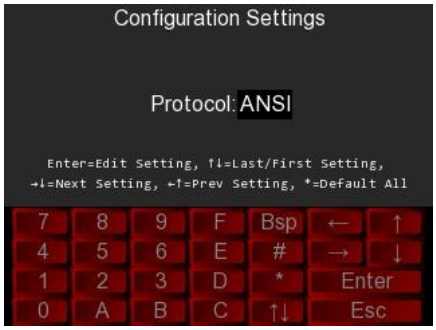


After the diagnostic information the display should enter the configuration mode and display the Configuration Settings screen:

Configuration Settings
Firmware Version: 0.3
Enter=Edit Setting, ↑↓=Last/First Setting,
→↓=Next Setting, ←↑=Prev Setting, *=Default All
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

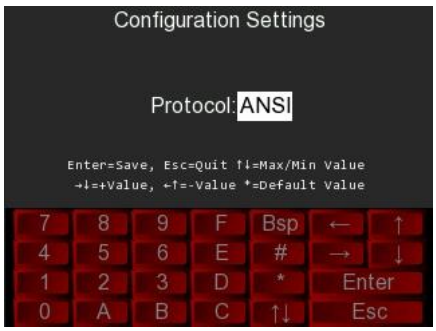
Configuring the Display

In Configuration Settings mode, the touch keypad is used to adjust or default User Configuration settings. In this mode, the touch keypad is displayed, and the ↑ and ↓ keys are used to scroll between configuration items, one at a time. Let's try it. Press and release the down arrow once. The screen shows the Protocol: setting.

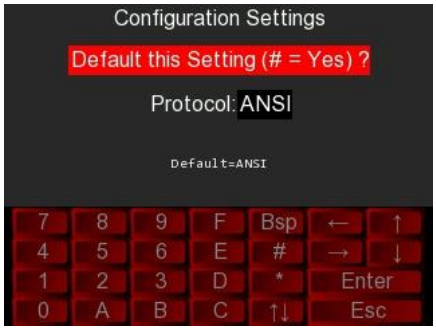

Configuration Settings
Protocol: ANSI
Enter=Edit Setting, ↑↓=Last/First Setting,
→↓=Next Setting, ←↑=Prev Setting, *=Default All
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

Notice that the fine print legend under the setting and above the keypad indicates that the ← and → keys can also be used to scroll between settings. Try scrolling between the various settings and notice how the settings wrap around after the End Of Config: 0 setting is reached.

The legend indicates that you can Edit a setting by pressing the Enter key. Try it – scroll to the Protocol: setting and press the Enter key. The setting highlights to show that it is being edited and the legend changes:

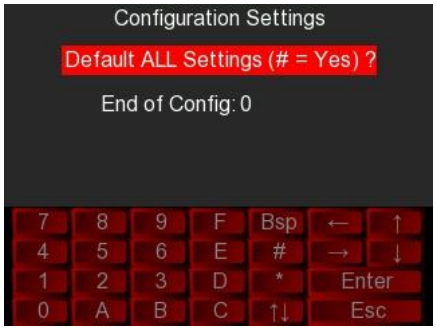

Configuration Settings
Protocol: ANSI
Enter=Save, Esc=Quit ↑↓=Max/Min Value
→↓=+Value, ←↑=-Value *=Default Value
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

Try changing the setting using the arrow keys. Note that the display supports five different Protocols and that the setting value doesn't wrap around. You can Save the setting at any time by pressing the Enter key again. You can also default the individual setting when editing it by pressing the * key. The Default this Setting question appears:



Some settings allow numeric entry of a new value via the number keys.

The legend also indicates that we can default all of the settings – probably a good idea so we start with a clean slate. Press and release the * key. The Default ALL Settings question appears:



If you press any key other than the # key, the question is answered NO and all the settings will not be defaulted.

Press and release the # key to answer yes. The settings are defaulted and the settings screen reverts to the first setting.

After defaulting, the display is configured to the (default) settings shown in the following table:

#	Setting	Description
00	Firmware Version	= version # of firmware
01	Protocol	0 = ANSI (default), 1 = SOH128Mono, 2 = SOH320Mono, 3 = SOH320Color, 4 = ACS Basic
02	Serial Baud Rate	1200, 2400, 4800, 9600 (default), 19200, 38400, 57600
03	Serial Data Bits	7, 8 (default)
04	Serial Stop Bits	1 (default), 2
05	Serial Parity	NONE (default), EVEN, ODD
06	ANSI Line Wrap	0 = no wrap (default), 1 = ANSI lines exceeding screen width wrap to next line
07	ANSI Add LF to CR	0 = CR (default), 1 = incoming CR replaced by CR/LF pair
08	ANSI Add CR to LF	0 = LF (default), 1 = incoming LF replaced by CR/LF pair
09	ANSI Local Echo	0 = no echo (default), 1 = echo
10	Display Comm Addr	0 = no address (default), xx = display's address for SOH/ETX protocol
11	Backlight on Recv	0 = disabled, 1 = backlight on for time when characters received
12	Backlight on Key	0 = disabled, 1 = backlight on for time when switch pressed
13	Backlight Timeout	= number of seconds backlight stays lit (default = 30)
14	Backlight On Level	0 = off, 12 = default, 15 = full brightness
15	Backlight Off Level	0 = off, 5 = default, 15 = full brightness
16	Send Key Opens	0 = no (default), 1 = yes
17	Power Up Disp Logo	0 = no logo upon reset, 1 = display graphic page 0 (logo) upon reset (default)
18	Power Up Disp Setng	0 = no settings shown upon reset, 1 = display settings screen upon reset (default)
19	Auto Clear Disp Sec	= number of seconds before display clears (default = 0, off)
20	Auto Clear DispLogo	= number of seconds before logo clears (default = 0, off)
21	RS485 Enable	0 = disabled (default), 1= enabled
22	Key Beep Enable	0 = disabled (default), 1 = enabled
23	Key Beep Frequency	262Hz, 440Hz, 880Hz, 1397Hz (default), 1760Hz, 2093Hz, 3520Hz
24	Key Beep Secs/50	= duration of key beep in fiftieths of a second (default = 12)
25	TPad in SOH Raw	= Touch Keypad characters sent outside of SOH/ETX protocol
26	TPad Show Up Left-X	= Touch Keypad Show upper left X coordinate (0 – 319) (default=270)
27	TPad Show Up Left-Y	= Touch Keypad Show upper left Y coordinate (0 – 239) (default=0)
28	TPad Show Lo Right-X	= Touch Keypad Show upper left x coordinate (0 – 319) (default=319)
29	TPad Show Lo Right-Y	= Touch Keypad Show upper left x coordinate (0 – 239) (default=48)
30	Power Up Quad Detect	= 0 no touchscreen quadrant detect upon reset, 1 = detect touchscreen quadrant held upon reset (default)
31	TPad Style	= NONE, QWERTY, NUMERIC, QWERTY TOP, NUMERIC TOP
32	TPad Scheme	= RED, GREEN, BLUE, GRAY 25%, GRAY 50%
33	PS/2 Enable	0 = disabled (default), 1 = enabled (requires external adaptor on EXP)
34	MAC Address	= 02:01:23:45:67:89 (default)
35	IP Address	= 192.168.1.200 (default)
36	IP Mask	= 255.255.255.0 (default)
37	Router IP Address	= 192.168.1.1 (default)
38	FTP Server Port	= 21 (default)
39	VNC Server Port	= 5900 (default)
40	HTTP Server Port	= 80 (default)
41	TCP/IP Raw Port	= 23 (default)
42	NTP Server	= 64.250.177.145 (default: nist1-atl.ustiming.org)
43	NTP Client Port	=123 (default)
44	End of Config	= end of configuration items placeholder
45	NV Status Byte	= NV status byte (default = 227)

Note that if you disable the Power Up Quad Detect you will have to use a hardware jumper to force the display into the Configuration Settings screen on power-up.

We'll start exercising the display using the ANSI protocol which is the default that you've now configured.

You can exit the configuration mode in two ways: by pressing the physical RESET button or by pressing the Esc (Escape) key on the keypad. Pressing the Esc key asks you to confirm that you wish to reset the display:

Using either of the two methods reset the display to exit the Configuration Settings mode.

Protocols

The ACS Color 320x240 LCD Display Terminal can operate in one of five protocol modes:

1. ANSI – receive and display ASCII characters and some ANSI sequences and send characters entered from either the pop-up keypad or optional PS/2 keyboard.
2. SOH128Mono – emulates the ACS 128x64 LCD by receiving and displaying messages formatted for that display and sends messages corresponding to an on-screen membrane keypad.
3. SOH320Mono – emulates the ACS 320x240 Monochrome LCD by receiving and displaying messages formatted for the display and sends messages or characters entered from either the pop-up keypad or optional PS/2 keyboard.
4. SOH320Color – displays color graphics and images and implements an optional screen/object application interface by receiving and interpreting messages and sends messages or characters entered from either the pop-up keypad, optional PS/2 keyboard or user interaction with screen objects.
5. Acs Basic – provides full display customization by scripting screen graphics, images and user interaction using programs written in an enhanced Beginners All-purpose Symbolic Instruction Code (BASIC) language.

The required protocol mode is established using the Configuration Settings screen described above. Let's look at how these different modes work.

ANSI Protocol

The ANSI subset protocol allows the display to be used as a limited ANSI terminal with scrolling. In this mode the display interprets the data received over the communications port as ANSI characters and command sequences and shows them on the display. Characters that are entered with the pop-up keypad or the optional attached PS/2 keyboard are sent out over the communications port.

The display consists of 20 lines of 45 characters shown using a fixed pitch 6 x 10 pixel font that is drawn in a 7 x 12 pixel matrix. The display supports the concept of a 'cursor', which is displayed as a blinking underline, and represents the insertion point on the display where the next printable character that is received will be placed.

The ANSI mode supports UTF-8 character coding. Receipt of byte values of printable US ASCII characters (32 decimal / 20 hex through 126 decimal / 7E hex) displays those characters. Extended characters may be displayed using a multi-byte UTF-8 sequence. See the "***ACS Color 320x240 LCD Display Terminal User's Manual , Displayed Characters Appendix"*** for details.

Receipt of these printable characters cause the display to show the character on the screen at the current cursor location, and then move the cursor right to the next position. Escape character sequences may be used to pre-position the cursor, clear one or more lines and/or set the coloring for subsequently displayed text.

There is a User Configuration setting that will automatically wrap the cursor to the beginning of the next line if required, scrolling the display up if the cursor was on the last line. There are also configuration settings to echo locally typed characters on the display, and perform common end of line character manipulation.

A large subset of ANSI command sequences are supported. These allow the cursor to be positioned and the text color to be changed. For a complete list of the supported ANSI sequences see the "***ACS Color 320x240 LCD Display Terminal User's Manual"***.

SOH/ETX Protocols

The SOH/ETX protocols allow full control of the display features and functionality, but require that the host computer properly format sequences of commands using the protocol to control the display, and interpret a formatted response to receive status and data from the display.

The SOH/ETX protocol starts each command or response with a single ASCII Start of Header control character = 01_{16} or CTRL-A, represented herein as **<SOH>** and ends each command with a single ASCII End of Text control character = 03_{16} or CTRL-C, represented herein as **<ETX>**.

Command or Response data arguments are sent as ASCII Hex strings one to four characters in length or as printable ASCII characters. Multiple fields may be delineated by embedded ASCII separator control characters depending upon the actual display mode.

SOH128Mono Mode

This display operating mode emulates most of the functions of the ACS-LCD-128x64 monochrome display. The pixels are drawn doubled in size and there is no support for the hardware keypad overlay – it is emulated on-screen:

Please refer to the separate document ***"ACS-LCD-128x64 User's Manual"*** for the serial protocol and commands.

SOH320Mono Mode

This display operating mode emulates most of the functions of the ACS-LCD-320x240 monochrome display. There is no support for a hardware keypad or input polling:

Please refer to the separate document ***"ACS-LCD-320x240 User's Manual"*** for serial protocol and commands.

SOH320Color Mode

This display operating mode provides an extended command set for operation of the display features. Commands are provided for drawing graphics, displaying bitmaps with transparency, printing UTF-8 text with user-supplied fonts and receiving touchscreen interaction. There is also a higher level screen and object model available to simplify user interaction with buttons and sliders and facilitate multiple screen navigation.

ACS Color Basic Programming

The protocol setting of ACS Basic is more of an operating mode than a communications protocol. This mode provides full access to all of the display's features using a superset of the Beginners All-purpose Symbolic Instruction Code – BASIC. The superset provides additional commands and enhancements for manipulating the display. You can develop programs in the ACS Color Basic to implement your application.

ACS Color Basic is an integer, microcomputer basic designed for simple control applications. The communications port is used to interactively develop one or more programs that perform the functions of the user's application. ACS Basic executes programs consisting of one or more statements. Statements consist of an optional line number followed by reserved keyword commands specifying operations for Basic to perform followed by required and / or optional arguments.

See the separate document ***"Color 320x240 LCD Basic Programming User's Manual"*** for more information on operating the display in this mode.

Starting with the ANSI Protocol

Let's get started using the ANSI Protocol mode. From the earlier section on ***"Configuring the Display"*** the Color LCD should be setup to use ANSI Protocol with the baud rate of 9600. If it is not configured for this please return to the earlier section and establish this configuration.

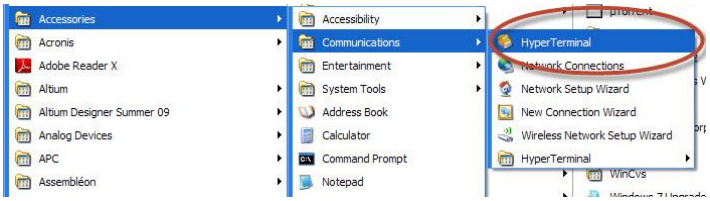
We will interact with the display using a terminal emulator and communication connection. If you haven't already done so, connect the Color LCD to your PC using either the SERIAL or USB connector as shown in the earlier section on "Providing Communication".

Now that the Color LCD is powered, connected and configured we need to start the terminal emulator. We will show how this is done for both Hyperterminal and Tera Term. The use of another terminal emulator would require a similar sequence of steps.

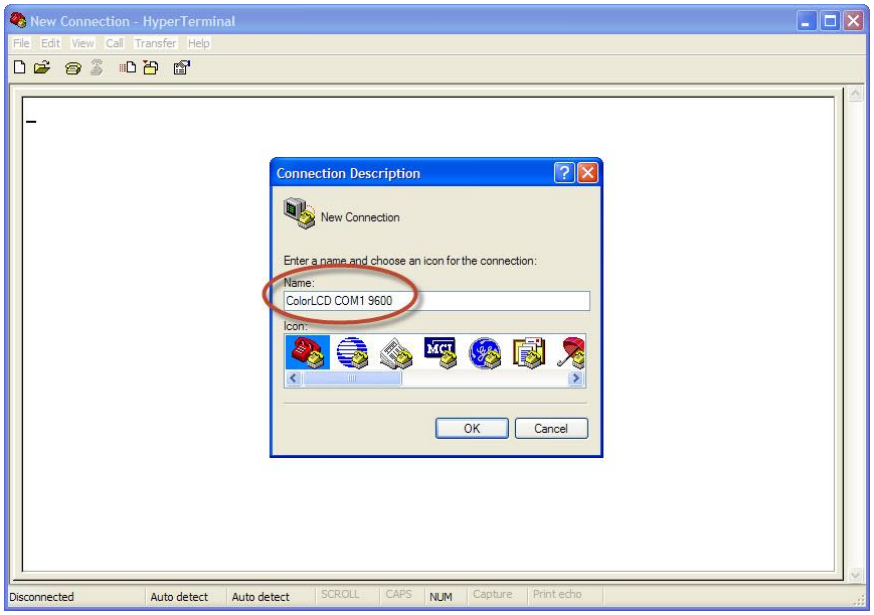
Communicating with Hyperterminal

The following steps are required to connect to the Color LCD using Hyperterminal.

1. Start Hyperterminal. On Windows XP you can navigate to the program via the Start Button, Accessories, Communications, Hyperterminal:



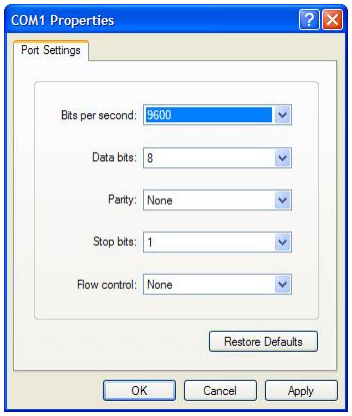
2. The Hyperterminal program starts and requests information for establishing a new connection. Enter the connection name and choose an icon to represent the connection. You may want to include the communications port and baud rate in the connection name:



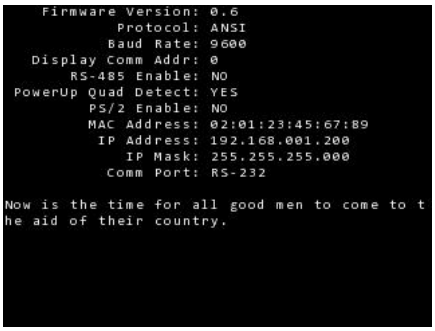
3. Hyperterminal requests what communications port you wish to connect to. Select the port that you have connected the Color LCD to with the Connect using drop down:

4. Configure the connection properties using the five drop down boxes to the following:

   a. Bits per second: 9600
   b. Data bits: 8
   c. Parity: None
   d. Stop bits: 1
   e. Flow control: None



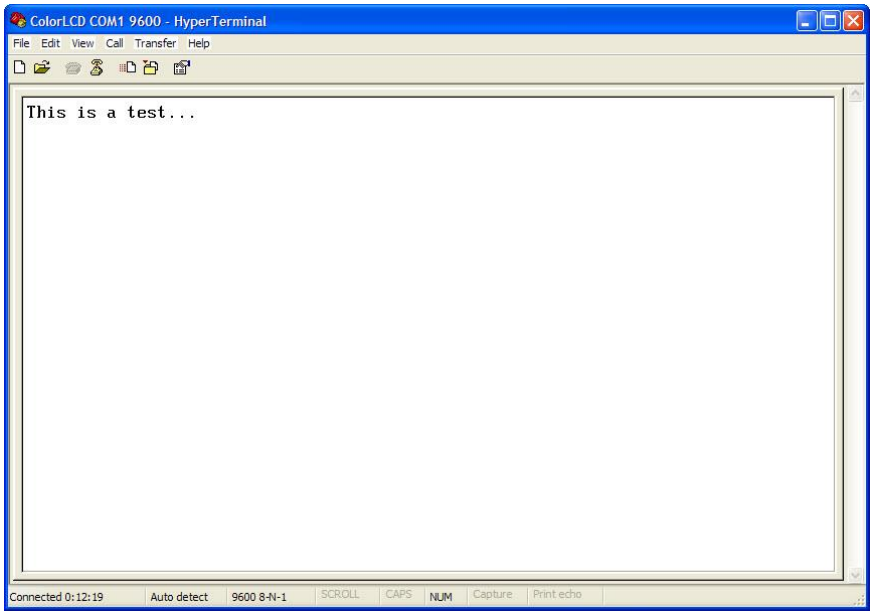
5. Hyperterminal should now be connected to the Color LCD. Try typing a few words – they won't show on the Hyperterminal window, but should show on the display. In this screen capture we typed "Now is the time for all good men to come to the aid of their country." Notice how the typed text wraps around to the next line on the display when it reaches the right-hand edge:



6. Now touch the Color LCD screen in the lower right hand corner. The pop-up keypad should appear at the top of the screen. The location and size of this 'hotspot' is configurable in the settings:

Es 1 2 3 4 5 6 7 8 9 0 - = Bs
Tab q w e r t y u i o p [ ]
Caps a s d f g h j k l ; " ↑↓
Shift z x c v b n m , . / Enter
Ctrl ` \ ↑ ↓ ← → Hide
Comm Port: RS-232
Now is the time for all good men to come to t
he aid of their country.

7. Try typing on the pop-up keypad. The characters that you type should appear in the Hyperterminal window:



8. Try some more communications in both directions. Now let's clear the Color LCD display by sending an ANSI command sequence. ANSI command sequences start with the ESCape character – the ESCape key is usually located on the upper left of the PC keyboard.

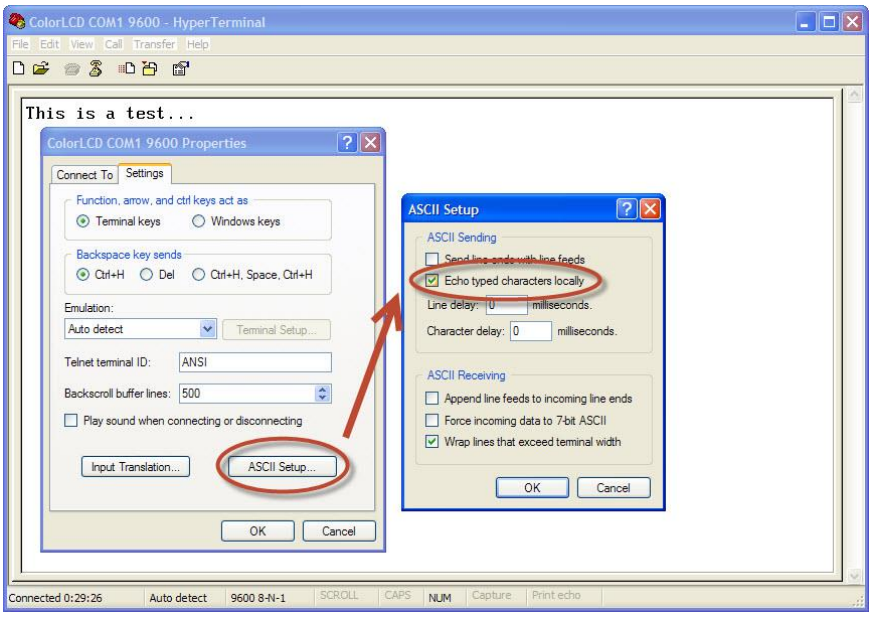
   The character sequence to clear the display is **ESC [2 J**. These characters must be sent in sequence without any spaces or other characters in-between. Try typing these characters into Hyperterminal and watch the Color LCD screen. If the screen didn't clear you didn't type the characters correctly, in the right sequence or without any spaces in-between.

The characters that you typed into Hyperterminal with the PC keyboard and into the Color LCD with the pop-up keypad didn't appear on the on the screen that you typed them into. If you want them to appear, you will have to enable a feature called "Local Echo" on each end – characters that are typed locally are echoed to the screen.

In the Color LCD this is controlled by a configuration setting:

Configuration Settings
ANSI Local Echo: YES
Enter=Save, Esc=Quit ↑↓=Max/Min Value
→↓=+Value, ←↑=-Value *=Default Value
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

In Hyperterminal this is configured using the File menu, Properties then ASCII Setup… button:



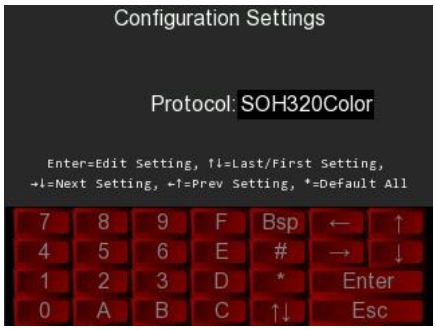
The local echo can cause problems if the system or program that you are communicating with is also echoing the characters that it is receiving – it will appear on the sending device as if each character was typed twice. If this happens you will have to disable local echo on the end of the communications port that is experiencing the double characters.

The ANSI Protocol is the easiest way to verify that proper two-way communication is occurring – verifying your wiring and also your settings on both ends of the communications channel.

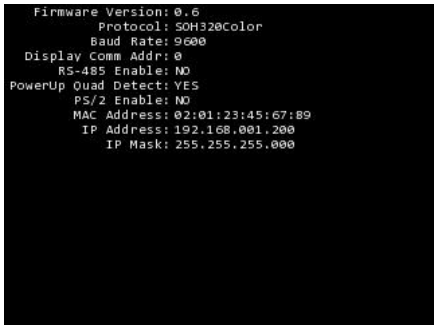
Moving to the SOH/ETX Protocol

Now that we have the ACS Color 320x240 LCD Display Terminal connected and communicating we can try another mode using a different protocol.

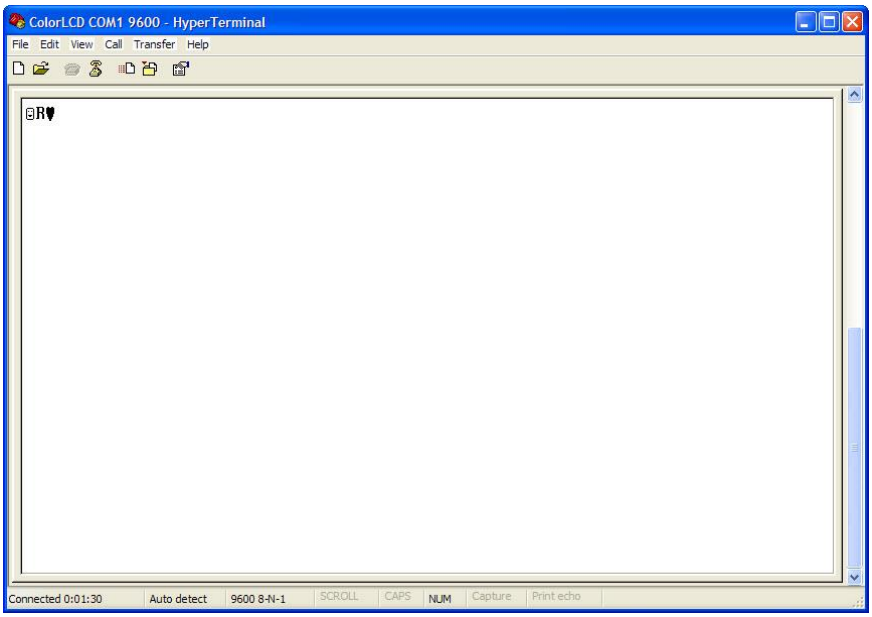
Configure the Color LCD protocol for SOH320Color in the Configuration Settings:


Configuration Settings
Protocol: SOH320Color
Enter=Edit Setting, ↑↓=Last/First Setting,
→↓=Next Setting, ←↑=Prev Setting, *=Default All
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

When you power-up or reset the display in this mode there is a resource loading status screen shown. This screen clears and the following screen should be momentarily displayed then cleared:



This screen should also clear and leave the display blank. At this time you should see the letter R displayed in your terminal emulator program:



The **R** is the display's Reset status message. The display is now ready to accept commands.

In this manual, the **<SOH>** and **<ETX>** are used as printed representations of single ASCII control characters:

> **<SOH>** Is the printed representation of a single ASCII Start of Heading character; CTRL-A, 01 decimal, 01 hex. This character delineates the start of a command or response in SOH/ETX the protocol modes.
>
> This character may be sent from your terminal emulator by holding down the Ctrl key and pressing the A key.
>
> **<ETX>** Is the printed representation of a single ASCII End of Text character; CTRL-C, 03 decimal, 03 hex. This character delineates the end of a command or response in SOH/ETX the protocol modes.
>
> This character may be sent from your terminal emulator by holding down the Ctrl key and pressing the C key.

The Reset status message is actually bracketed with **<SOH>** and **<ETX>** characters, but the terminal emulator shows the non-printing characters as a smiley face ☺ for the **<SOH>** character and a heart ♥ for the **<ETX>** character - if the View, Font is set to Terminal.

Drawing Graphics

Let's draw a white diagonal line across the display. Looking in the ***"Color 320x240 LCD Display Terminal User's Manual, SOH320Color, Draw Commands"*** section we find the following command template for drawing a line:

Draw Line

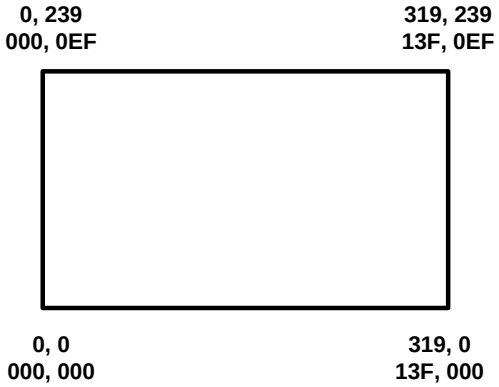
Draws a single color line on the current draw surface between the two coordinates:

<SOH> dl XXX YYY xxx yyy CCCC <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
dl	Draw Line	Command/modifier
XXX	Line Starting X Coordinate	3-digit ASCII Hex 000-13F
YYY	Line Starting Y Coordinate	3-digit ASCII Hex 000-0EF
xxx	Line Ending X Coordinate	3-digit ASCII Hex 000-13F
yyy	Line Ending Y Coordinate	3-digit ASCII Hex 000-0EF
CCCC	Line Color	4-digit ASCII Hex RGB565
<ETX>	End of Text	Ctrl-C (Hex 03)

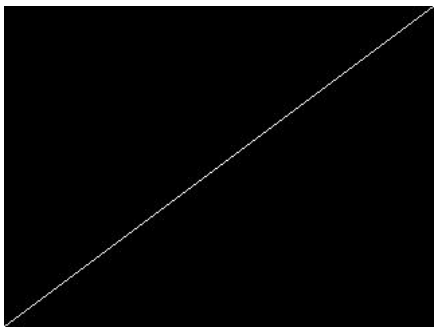
At the beginning of the Drawing section the screen coordinates are defined - the X and Y coordinates for drawing start at **0, 0** at the lower left corner of the display and range to 319, 239 at the upper right corner. The hex values of each corner coordinate are shown below each pair:



We should be able to draw this diagonal line by sending the following characters to the display by typing them into your connected terminal emulator (***without the spaces***):

Ctrl-A dl 000 000 13F 0EF FFFF Ctrl-C

The display screen should now look like:



If your display doesn't look like this try typing the command again making sure that you typed all of the letters correctly and that there aren't any spaces.

Now draw a red circle. Looking in the User's Manual to the Draw Circle command we find the following command template:

Draw Circle

Draws a single color circle on the current draw surface with a radius at the center coordinates:

<SOH> dc XXX YYY RRR CCCC <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
dc	Draw Circle	Command/modifier
XXX	Circle Center X Coordinate	3-digit ASCII Hex 000-13F
YYY	Circle Center Y Coordinate	3-digit ASCII Hex 000-0EF
RRR	Circle Radius	3-digit ASCII Hex 000-13F
CCCC	Circle Color	4-digit ASCII Hex RGB565
<ETX>	End of Text	Ctrl-C (Hex 03)

To draw this in the center of the screen, the Center X Coordinate should be 320 / 2 = 160 = 0A0 in hex. The Center Y Coordinate should be 240 / 2 = 120 = 078 in hex. Try using a radius of 48 = 030 in hex.

The last command parameter is the color. In the Manual Conventions at the beginning of this manual, there is a definition for RGB565:

RGB565

Is the printed representation of a 16-bit color comprised of 5 bits of Red, 6 bits of Green and 5 bits of Blue:

15 MSB	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 LSB
Red					Green						Blue				

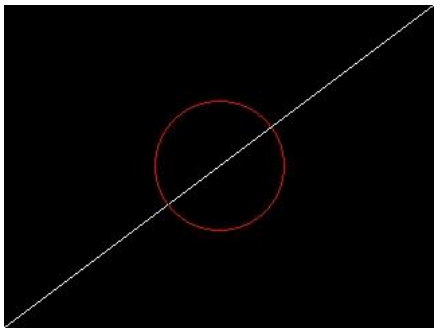
To draw a bright red circle, the leftmost five red bits would all be ones, and the rest would be zero. Translating these RGB565 bit fields to 4-bit hexadecimal fields:

	15 MSB	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0 LSB
	Red					Green						Blue				
Binary	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Hex	F				8				0			0				

So a bright red ASCII HEX RGB565 color would be F800 in hex. We should be able to draw this circle by sending the following characters to the display by typing them into your connected terminal emulator (***without the spaces***):

Ctrl-A dc 0A0 078 030 F800 Ctrl-C

The display screen should now look like:



Try some of the other Draw commands using different colors to see how they work.

Drawing Text

Let's add some text. Looking ahead at the Drawing commands we find the following template for drawing text:

Draw Text

Draws a UTF-8 text string on the current draw surface using the specified font at the coordinates:

<SOH> dt FF XXX YYY textString <ETX>

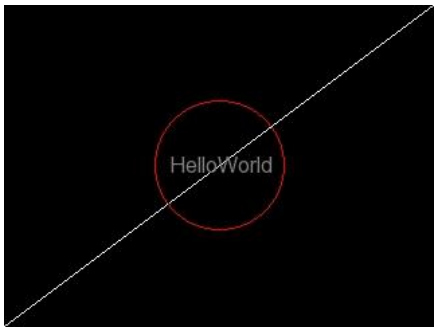
Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
dt	Draw Text	Command/modifier
FF	Font Number	2-digit ASCII Hex 00-1F
XXX	Text X Coordinate	3-digit ASCII Hex 000-13F
YYY	Text Y Coordinate	3-digit ASCII Hex 000-0EF
textString	Text to be drawn	8-bit UTF-8 text string
<ETX>	End of Text	Ctrl-C (Hex 03)

So let's print HelloWorld in the center of the screen. We will use font number 00 which defaults to a built-in font that the display uses for diagnostics. Type the following command (***without the spaces***):

Ctrl-A dt 00 0A0 078 HelloWorld Ctrl-C

The display screen should now look like:



The actual font color will depend upon the configured TPad Scheme – when the display resets the fonts are initialized from the configured, built-in scheme.

On your terminal emulator you should see a response from the **dt** command:

dts004F0016

Looking ahead to the Draw Text section of the manual, we can see that this is a response from the draw text command:

This command returns a response containing the width and height of the drawn text string to facilitate chaining /aligning subsequent text:

<SOH> dts WWWW HHHH <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
dts	Draw Text Size	Response/modifier/parameter
WWWW	Drawn Text Width	4-digit ASCII Hex 0000-013F
HHHH	Drawn Text Height	4-digit ASCII Hex 0000-00EF
<ETX>	End of Text	Ctrl-C (Hex 03)

This text is being drawn with Font #00. Fonts are a 'resource' used by other commands and objects and are controlled by entries in two tables.

The first requirement for font usage is an embedded font file that is loaded into the Resource table. There are two or more embedded fonts built-in to the display, and more can be loaded from the on-board serial flash or micro SD card memory.

The second requirement for font usage is an entry in the Font table that links the name of the embedded font resource with other font attributes such as color, transparency, spacing and alignment.

You can query the display for Font #00's attributes, and then issue other commands to change them. Looking ahead in this manual to the Query commands you can see that there are commands to Query Fonts and Resources. The command template for a font query command is:

Query Font Item

The Query Font Item command returns a response showing the requested font item's current value:

<SOH> qti NN <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
qti	Query Font Item	Command/modifier/parameter
NN	Font Number	2-digit ASCII Hex 00-FF
<ETX>	End of Text	Ctrl-C (Hex 03)

To see the attributes for Font #00 type the following Query Font Item command (***without the spaces***):

Ctrl-A qti 00 Ctrl-C

On the terminal emulator you should see the response from the **qti** command:

☺qt0▼AcsDefaultFont.efnt▼16▼0▼8410▼0▼0▼1▼1▼1▼0▲♥
☺qt0↔♥

Again, there are the bracketing **<SOH>** (☺) and **<ETX>** (♥) characters, and, in addition the individual fields of the response are delineated by embedded **<US>** (▼) characters with the record ending with a **<RS>** (▲) character. The end of the response is indicated by the trailing **qt0** followed by the **<GS>** (↔) character. The terminal emulator typically doesn't show these non-printing control characters – some programs can.

Here's a display of the same response using the Indigo Terminal Emulator:

<SOH>qt0<US>AcsDefaultFont.efnt<US>16<US>0<US>8410<US>0<US>0<US>1<US>1<US>1<US>0<RS><ETX><CR><LF>
<SOH>qt0<GS><ETX><CR><LF>

Looking at these fields we can determine the following information about Font #0:

Field	Field Name	Value
☺ = <SOH>	Start of Header	Ctrl-A (Hex 01)
qt	Query Font	Response/modifier
0	Font Number	Font #0
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
AcsDefaultFont.efnt	Font File Resource Name	Name of loaded .EFNT resource
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
16	Font Height	16 = 22 pixels high
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Font Background Color	0 = Black
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
8410	Font Foreground Color	8410 = Grey
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Font Spacing-X	0 = fixed width of the font

Field	Field Name	Value
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Font Spacing-Y	0 = fixed width of the font
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
1	Font Horizontal Alignment	1 = Center Justify
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
1	Font Vertical Alignment	1 = Center Justify
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
1	Background Transparency	1 = Transparent
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Foreground Transparency	0 = Solid
▲ = <RS>	Record Separator	Ctrl-^ (Hex 1E)
♥ = <ETX>	End of Text	Ctrl-C (Hex 03)

This font item record is followed by the group delimiter record indicating the end of this response:

<SOH>qt0<GS><ETX><CR><LF>

Field	Field Name	Value
<SOH>	Start of Header	Ctrl-A (Hex 01)
qt	Query Font	Response/modifier
0	Font Number	Font #0
↔ = <GS>	Group Separator	Ctrl-] (Hex 1D)
<ETX>	End of Text	Ctrl-C (Hex 03)

Let's change font number 00 to be white foreground letters on a red background. To do this you have to change the Font Background Color, the Font Foreground Color and the Background Transparency. Looking ahead in this manual to the Font commands you can see that there are commands to set the Font Colors and Font Attributes.

The command template for the command to set the Font Colors is:

Font Colors

Sets the background and foreground colors used to draw this font table entry:

<SOH> fc FF BRGB FRGB <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
fc	Font Color	Command/modifier
FF	Font Table entry number	2-digit ASCII Hex 00-1F
BRGB	Font Background Color	4-digit ASCII Hex RGB565
FRGB	Font Foreground Color	4-digit ASCII Hex RGB565
<ETX>	End of Text	Ctrl-C (Hex 03)

To set the background color to red and the foreground color to white type the following command (***without the spaces***):

Ctrl-A fc 00 F800 FFFF Ctrl-C

The command template for the command to set the Font Attributes is:

Font Attributes

Sets the background and foreground colors used to draw this font table entry:

<SOH> fa FF X Y H V B F <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)

Field	Field Name	Notes
fa	Font Attribute	Command/modifier
FF	Font Table entry number	2-digit ASCII Hex 00-1F
X	Font Spacing-X	1-digit ASCII Hex: 0 = fixed width of the font 1→E = pixels between characters F = bounding box character width
Y	Font Spacing-Y	1-digit ASCII Hex: 0 = fixed width of the font 1→E = pixels between characters F = bounding box character width
H	Font Horizontal Alignment	1-digit ASCII Hex: 0 = Left Justify 1 = Center Justify 2 = Right Justify
V	Font Vertical Alignment	1-digit ASCII Hex: 0 = Top Justify 1 = Center Justify 2 = Bottom Justify
B	Background Transparency	1-digit ASCII Hex: 0 = Solid 1 = Transparent
F	Foreground Transparency	1-digit ASCII Hex: 0 = Solid 1 = Transparent
<ETX>	End of Text	Ctrl-C (Hex 03)

To set the background transparency to solid (and keep the other font attributes the same type the following command (without the spaces):

Ctrl-A fa 00 0 0 1 1 0 0 Ctrl-C

You can verify that the colors and attributes have been set by using the Query Font Item command again:

Ctrl-A qti 00 Ctrl-C

Now the response should be:

☺qt0▼AcsDefaultFont.efnt▼16▼F800▼FFFF▼0▼0▼1▼1▼0▼0▲♥
☺qt0↔♥

Looking at these fields we can verify that we changed Font #0:

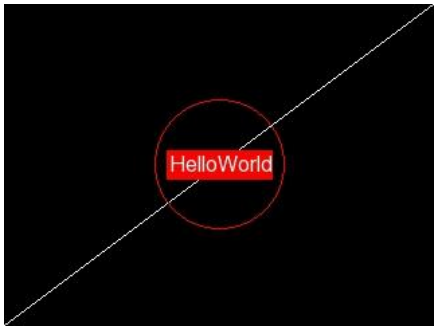
Field	Field Name	Value
qt	Query Font	Response/modifier
0	Font Number	Font #00
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
AcsDefaultFont.efnt	Font File Resource Name	Name of loaded .EFNT resource
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
16	Font Height	0016 = 22 pixels high
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
F800	Font Background Color	F800 = Red
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
FFFF	Font Foreground Color	FFFF = White
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Font Spacing-X	0 = fixed width of the font
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Font Spacing-Y	0 = fixed width of the font

Field	Field Name	Value
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
1	Font Horizontal Alignment	1 = Center Justify
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
1	Font Vertical Alignment	1 = Center Justify
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Background Transparency	0 = Solid
▼ = <US>	Unit Separator	Ctrl-_ (Hex 1F)
0	Foreground Transparency	0 = Solid
▲ = <RS>	Record Separator	Ctrl-^ (Hex 1E)
♥ = <ETX>	End of Text	Ctrl-C (Hex 03)

Issue the same Draw Text command by typing the following command (***without the spaces***):

Ctrl-A dt 00 0A0 078 HelloWorld Ctrl-C

The display screen should now look like:



Try changing the other Font Attributes to see the results.

Clearing the Display

So, how do we clear the display? Again looking ahead to the Draw commands we don't see a Clear sub-command, but there is a Fill. The display is cleared by filling the screen with the desired color. Here's the command description:

Draw Fill Flat

Fills an area of the current draw surface defined by a lower-left coordinate, width and height with a constant color:

<SOH> dff XXX YYY WWW HHH CCCC <ETX>

Where:

Field	Field Name	Notes
<SOH>	Start of Header	Ctrl-A (Hex 01)
dff	Draw Fill Flat	Command/modifier/parameter
XXX	Lower-left Fill X Coordinate	3-digit ASCII Hex 000-13F
YYY	Lower-left Fill Y Coordinate	3-digit ASCII Hex 000-0EF
WWW	Fill Width	3-digit ASCII Hex 000-140
HHH	Fill Height	3-digit ASCII Hex 000-0F0
CCCC	Fill Color	4-digit ASCII Hex RGB565
<ETX>	End of Text	Ctrl-C (Hex 03)

To clear the screen to black, issue a Draw Fill Flat command that covers the entire screen with the color black (0000):

Ctrl-A dff 000 000 140 0F0 0000 Ctrl-C

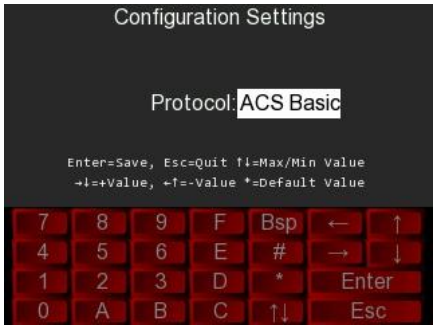
The screen should now be blank (black).

Trying ACS Color Basic Programming

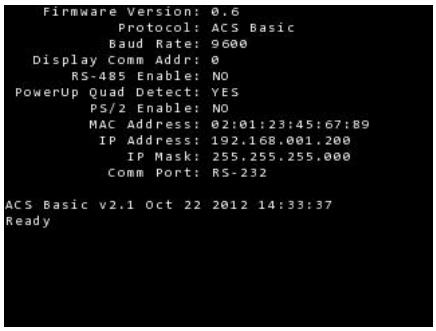
Now that we have the ACS Color 320x240 LCD Display Terminal connected and communicating we can try another mode using the fifth protocol – ACS Basic.

First configure Hyperterminal to not echo local characters since Basic will be echoing any characters that it receives.

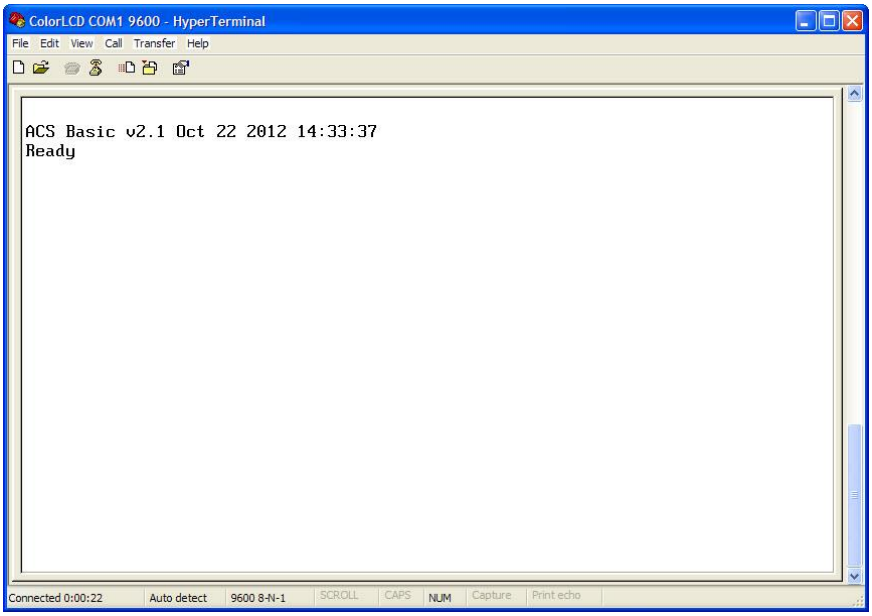
Then configure the Color LCD protocol for ACS Basic in the Configuration Settings:


Configuration Settings
Protocol: ACS Basic
Enter=Save, Esc=Quit ↑↓=Max/Min Value
→↓=+Value, ←↑=-Value *=Default Value
7 8 9 F Bsp ← ↑
4 5 6 E # → ↓
1 2 3 D * Enter
0 A B C ↑↓ Esc

Now when the Color LCD is reset notice the ACS Basic sign on message and Ready prompt:



Notice that the same sign on message and Ready prompt appear on Hyperterminal:



In this mode the Color LCD understands a language called ACS Basic. ACS Basic is a customized form of the "Beginners All-purpose Symbolic Instruction Code". The original Basic was developed back in 1964 to provide computer access to people who didn't usually program. This version provides additional commands and features that make it useful to program an interactive display.

Talking to the Color LCD in ACS Basic

Try pressing the Enter key on your PC's keyboard. The Color LCD display indicates that it is awaiting instruction by responding with Ready. Ready is the display's prompt – it is waiting for a command from you.

Try typing the following as your first command – type this exactly as it is shown:

```
PRINT "Hello World"
```

When you reach the end of the line, review it for mistakes. Did you put the quotation marks where they were shown? If you made a mistake, simply press the backspace key and the last character that you typed will disappear. You can backspace over the entire line if necessary.

Your PC (and display screen) should look like this:

```
Ready
PRINT "Hello World!"
```

Now press the Enter key and see what happens. Your screen should now look like this:

```
Ready
PRINT "Hello World!"
Hello World!
Ready
```

The Color LCD display executed the command that you entered by printing the message that you had in quotes.

Now let's try another command:

```
PRINT "2 + 2"  Enter
```

The Color LCD executes your command by printing:

```
2 + 2
Ready
```

If you expected to see the number four, then try removing the quotation marks:

```
PRINT 2 + 2  Enter
```

The Color LCD executes your command by printing:

```
4
Ready
```

The Color LCD sees everything that you type as either Strings or Numbers. If it's in quotes, it's a String and the display sees it exactly as it was typed. If it's not in quotes it's a Number. The Color LCD will figure it out like a numerical problem. It it's not in quotes the display can interpret it by adding, subtracting, multiplying or dividing it.

Let's try a multiplication problem:

```
PRINT 1589 * 2  Enter
```

```
PRINT 1589 * 2
3178
Ready
```

The Color LCD uses an asterisk as a multiplication sign rather than an X since the X character is alphabetical and can be part of a name as we will see later.

There Are Rules…

The Color LCD is very literal. If it doesn't understand what you have typed it will produce an error message to let you know. Try typing this line deliberately misspelling the word PRINT:

PRIINT "HI" Enter

The Color LCD prints:

```
PRIINT "HI"
Syntax error - no equals
Ready
```

The display doesn't understand what you have typed. The "Syntax error" message indicates that the command "PRIINT" is not one that it knows how to do. It also tries to provide additional information to help you figure out the error, "- no equals", but in this case it is confused and this doesn't help.

Try leaving off the last quotation mark. Type:

PRINT "HI Enter

The Color LCD prints:

```
PRINT "HI
Mis-matched quotes error
Ready
```

The Color LCD will also give you error messages when it does understand what you have typed, but the command will result in incorrect operation. For instance, try typing:

PRINT 5 / 0 Enter

The display prints:

```
PRINT 5 / 0
Divide by zero error
Ready
```

This error message indicates that you're asking it to divide by zero – which is not possible.

Remembering Numbers and Strings

One of the features of the Color LCD is the ability to remember things you ask it to. For example, to make the display remember the number 13, type this:

```
A = 13 Enter
```

Now try the other PRINT commands that you did before. To see if the display still remembers what A is equal to, type:

```
PRINT A Enter
```

And the display should print:

```
PRINT A
13
Ready
```

The Color LCD remembers that the placeholder A has the number value of 13 until you turn it off or change it. Type:

```
A = 17 Enter
```

```
A = 17
Ready
PRINT A
17
Ready
```

So what happened? When you first set A equal to 13 the display created a named memory location to hold that value. You can refer to that location by the name A to retrieve the current value of the memory location as with the PRINT A command above. You can also modify the value of the named memory location by setting it to a new value. You can use combinations of letters and numbers to name these memory locations – the only requirement is that the name must not start with a number. Try typing these commands:

```
B = 15 Enter
```

```
C2 = 20 Enter
```

```
LongName = 25 Enter
```

Now ask the Color LCD to retrieve all of these numbers by name. Type:

```
PRINT A, B, C2, LongName Enter
```

And the display should show:

```
PRINT A, B, C2, LongName
17 15 20 25
Ready
```

To get the Color LCD to remember strings of letters or numbers, put a dollar sign at the end of the name. Type:

```
A$ = "Remember" Enter
```

```
B$ = "this for me" Enter
```

And then ask the display to display them:

```
PRINT A$, B$
Remember this for me
Ready
```

In computer terminology these named memory locations are referred to as ***variables***. The Color LCD keeps track of these variables and their current values for you. You can ask it for a list of what variables it is currently remembering by typing the command:

```
VARS Enter
```

And the display will show the variables that we've used so far along with their current contents:

```
VARS
A                               R/W Int         = 17
B                               R/W Int         = 15
C2                              R/W Int         = 20
LongName                        R/W Int         = 25
A$                              R/W Str$        = "Remember "
B$                              R/W Str$        = "this for me"
Ready
```

The **R/W** indicates that the variable can be both **R**ead from and **W**ritten to. Later on we will see how to make variables **R**ead **O**nly. The **Int** indicates that the display understands this variable to be for holding Numbers, **Str$** indicates that the variable holds strings.

And of course the Color LCD is picky about what is stored in the two types of variables. Try typing these lines:

D = "6" Enter

D$ = 6 Enter

With both of these lines the display responds with an error message:

```
D = "6"
Wrong expression type error - can't assign string to numeric var
Ready
D$ = 6
Wrong expression type error - can't assign number to string var
Ready
```

In computer terminology, setting variables to values is referred to as ***assigning a value to a variable***.

There are four fundamental rules for variable value assignment:

Rules for Numeric Data

1. Numbers not in quotes are Numeric Data
2. Numeric Data can only be assigned to variables named without a trailing dollar sign

Rules for String Data

1. Any data in quotes is String Data
2. String Data may only be assigned to variable name with a trailing dollar sign

Variable Rules

1. You may use multiple characters from the upper case letters A-Z, the lower-case letters a-z, the numbers 0-9 and the '_' underscore character for variable names.
2. The first character of the name must be a letter, not a number or underscore.
3. Variable names are case-sensitive: **Aname** is not the same as **aNAME**.
4. Variables whose names end with a dollar sign can only hold String Data, otherwise they can only hold Numeric Data.
5. The list of current variables can be shown with the VARS command.
6. Short, concise variable names take less memory and work faster.

Remembering Commands

First we need to erase everything that the Color LCD has remembered so far. Type:

```
NEW Enter
```

Now type this command line: Be sure and type the number 10 first:

```
10 PRINT "Hello from the Color LCD" Enter
```

Notice that this time, when you pressed Enter nothing appeared to have happened. Not that you can immediately see. What you did was to type your first program. Type:

```
RUN Enter
```

The display now runs your program. You can type RUN again and again. You can also type run – ACS Basic's commands are not case-sensitive, just variable names:

```
10 PRINT "Hello from the Color LCD"
RUN
Hello from the Color LCD
Ready
run
Hello from the Color LCD
Ready
```

So the number at the beginning of the line tells Basic to store the line instead of executing it. Let's add another line to the program. The number at the beginning of the line is the "line number". Type:

```
20 print "What's your name?" Enter
```

Now let's ask the Color LCD to show us the entire program. Type:

```
LIST Enter
```

The display LISTs your entire program so far – notice how the lower-case print command was capitalized and how the lines are stored and shown in line number order:

```
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
Ready
```

Now run the program: Type: RUN Enter The Color LCD prints:

```
RUN
Hello from the Color LCD
What's your name?
Ready
```

Try answering the question by typing your name and pressing Enter . . . there's that Syntax error again – the display didn't understand what you meant when you typed in your name:

```
RUN
Hello from the Color LCD
What's your name?
Ready
Steve
Syntax error - no equals
Ready
```

In fact you have to instruct the Color LCD to accept your answer by giving it a command, INPUT, to do so. Add this line to the program:

```
30 INPUT Name$ Enter
```

The INPUT command tells the display to stop and wait for you to type something which it will assign to the variable Name$. Add one more line to the program to show the Name that was entered:

```
40 PRINT "Hi, ", Name$ [Enter]
```

Now LIST the program. It should look like:

```
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 PRINT "Hi,", Name$
Ready
```

Now let's RUN the program:

```
RUN
Hello from the Color LCD
What's your name?
? Steve
Hi, Steve
Ready
```

You can run the program many times, answering the question with different names – the display doesn't care what name you use. After each RUN the variable Name$ holds the last name you entered.

You can make your program run over and over without having to type the RUN command each time. Add this line to the program:

```
50 GOTO 10 [Enter]
```

Now RUN the program. It runs over and over without stopping. The GOTO command told the Color LCD to go back up to line 10. Your program will repeat over and over because every time it executes line 50 it jumps back to line 10. In computer terminology this is referred to as a ***loop***. The only way to stop this endless loop is to press the [esc] key twice in a row followed by the [Enter] key. This is known as ESCaping the program and the display tells you that you escaped:

```
Hello from the Color LCD
What's your name?
? [esc] [esc] [Enter]
 ESC at line 30
Ready
```

In this program the [Enter] key was required following the double [esc] key because the Color LCD was waiting for the [Enter] key at the INPUT command. If the display is not waiting for INPUT the double [esc] key is sufficient to ESCape the program.

Changing your Program

So how can you modify your program without typing NEW and starting over each time? To replace an existing program line simply type the new line using the same line number at the beginning of the line you want to replace. Type:

```
50 GOTO 40 [Enter]
```

Your program should now look like:

```
50 GOTO 40
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 PRINT "Hi,", Name$
50 GOTO 40
Ready
```

This program change modifies the loop to not ask the question over and over. Instead the program now just keeps repeatedly PRINTing the Name$ that you INPUT the first time. Press the [esc] key twice in a row to ESCape the program when you've seen enough. Notice that you don't need to press the [Enter] key to ESCape this time because the display is not waiting for INPUT:

```
RUN
Hello from the Color LCD
What's your name?
? Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve
Hi, Steve [esc] [esc]
 ESC at line 40
Ready
```

To remove a line from your program simply type the line number followed by the [Enter] key. This erases that line from your program. Type:

```
50 [Enter]
```

This removes line 50 from your program:

```
50
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 PRINT "Hi,", Name$
Ready
```

Put line 50 back into your program. Type:

```
50 GOTO 40 [Enter]
```

Now let's change the way that the PRINT shows your name. Replace line 40 in your program by typing it again, but add a semicolon at the end:

```
40 PRINT "Hi,", Name$; [Enter]
```

Now RUN the program. Notice how the trailing semicolon crams everything together?

```
40 PRINT "Hi, ", Name$,
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 PRINT "Hi, ", Name$,
50 GOTO 40
Ready
run
Hello from the Color LCD
What's your name?
? Steve
Hi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi,
SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi,
SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi,
SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi,
SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi,
SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, SteveHi, Ste ESC at line 40
Ready
```

Controlling the Program Execution

You've seen that a program can be RUN from lowest line number to highest. The program can also loop using the GOTO command. And a running program may be ESCaped to stop.

Another way to control the execution of a program is to GOTO only if a certain condition is met. Let's change our program so that it stops if we enter a blank name. Modify line 40 to remove the trailing comma by typing:

```
40 PRINT "Hi,", Name$ Enter
```

Now replace line 50 with a new IF / THEN command. The new IF / THEN command evaluates a condition, and, IF the condition is True, THEN it executes the commands after the THEN. Otherwise execution continues with the following program line. Type:

```
50 IF Name$ <> "" THEN GOTO 20 Enter
```

In this example the IF condition that is being evaluated is: **Name$ < > ""**. Name$ is the variable that receives your INPUT up until the Enter key. The < > (less than, greater than) stands for "not equal to", and the "" is an empty string – a string with no characters in it. So your program should now look like:

```
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 PRINT "Hi,", Name$
50 IF Name$ <> "" THEN GOTO 20
Ready
```

Run the program. Try entering your name the first time your program asks for it, then the next time simply press the Enter key. Notice how the program loops back to line 20 when your name was INPUT otherwise the program stops:

```
RUN
Hello from the Color LCD
What's your name?
? Steve Enter
Hi, Steve
What's your name?
? Enter
Hi,
Ready
```

When you press the Enter key in response to the INPUT command without typing any characters first, the INPUT variable receives an empty string otherwise the variable holds any characters that were typed in before the Enter key.

You can think of line 50 as reading: IF variable Name$ not equal to empty string THEN GOTO line 20. And that is exactly what the program is doing. However there is an error. In computer terminology this is called a ***program bug***. Notice how the program still prints Hi, before it stops when nothing is ENTERed. This is because the program executes line 40 before it checks for Name$ being empty. In order to fix this 'bug' we have to check for the stop condition before we PRINT the Name$.

Replace line 40 with the new IF / THEN check. Type:

```
40 IF Name$ = "" THEN STOP Enter
```

And then replace line 50 with the PRINT command. Type:

```
50 PRINT "Hi,", Name$ Enter
```

The program should now look like:

```
LIST
10 PRINT "Hello from the Color LCD"
20 PRINT "What's your name?"
30 INPUT Name$
40 IF Name$ = "" THEN STOP
50 PRINT "Hi,", Name$
60 GOTO 20
Ready
RUN
Hello from the Color LCD
What's your name?
? Steve
Hi, Steve
What's your name?
?
STOP in line 40
Ready
```

The new STOP command does exactly that – it stops the program from running and shows you what line the program stopped on. You can also use the END command which stops without the message. Try it by changing line 40.

Program Rules

1. A program consists of one or more command lines that begin with a line number.
2. Commands are not case-sensitive but are converted by Basic. Variables are case-sensitive.
3. Program lines and variables may be cleared from memory by the NEW command.
4. Program lines are kept in ascending numeric order by the display.
5. A program is RUN to execute the lines in numeric order starting with the lowest numbered line.
6. Program lines may be shown with the LIST command.
7. The execution order of program lines may be changed by the GOTO command.
8. A program which is executing repeatedly in a loop may be ESCaped by pressing the esc key twice in a row.
9. A program line may be replaced by typing a new program line with the same line number.
10. A program line may be deleted by typing the line number only followed by Enter.
11. Program line execution may be conditioned by the IF / THEN command.
12. Program execution may be stopped with the STOP or END commands.

Learning How to Count

Most programs require the ability to count – lines, key presses, characters, loops or other things. With the commands that you already know you can write a program that counts.

First we need to learn a fundamental concept. In order to add to a variable you can use it on each side of the assignment equals sign. For example, type:

```
A = 1 Enter
PRINT A Enter
A = A + 1 Enter
PRINT A Enter
```

With assignment A = A + 1, the current value of A has one added to it then it becomes the new value of A. The value to add doesn't have to be 1, it can also be the value of another variable. You can read this statement as "Variable A equals the value of Variable A plus 1".

So in order to count from 1 to 10 we can write the following short program. Start fresh by typing:

```
NEW Enter
```

First we set the value of the counter, A, equal to 1. Type:

```
10 A = 1 Enter
```

Then we print it. Type:

```
20 PRINT A Enter
```

Then we add one to it. Type:

```
30 A = A + 1 Enter
```

Then we check to see if A is less than or equal to 10… and, if so, we loop back to print the new value. Otherwise we're done counting:

```
40 IF A <= 10 THEN GOTO 20 Enter
```

Now list the program. It should look like:

```
LIST
10 A = 1
20 PRINT A
30 A = A + 1
40 IF A <= 10 THEN GOTO 20
Ready
```

Now RUN it:

```
RUN
1
2
3
4
5
6
7
8
9
10
Ready
```

Simple – right? However, ACS Basic provides another way to count with fewer commands that's a little easier to read.

Start fresh by typing NEW Enter again. Now we will work with a new two command combination: FOR / NEXT.

The FOR command replaces two commands: line 10 - the setting of the initial count value, and line 40 – the check for the end count value. The NEXT command replaces two commands: line 30 – the advance of the count value, and the GOTO portion of line 40 – the counting loop. Let's see how this works.

First the FOR command. This command determines the count variable, its initial value and the ending value. Type:

```
10 FOR A = 1 TO 10 Enter
```

Now as before we PRINT the count value. Type:

```
20 PRINT A Enter
```

And finally the NEXT command. This command advances the count value and executes the loop if more counting is necessary. This is referred to as closing the loop. Type:

```
30 NEXT A Enter
```

Now list the program. It should look like:

```
LIST
10 FOR A = 1 TO 10
20 PRINT A
30 NEXT A
Ready
```

Now RUN it:

```
RUN
1
2
3
4
5
6
7
8
9
10
Ready
```

This program is one line shorter, but does the same thing. It is also easier to read and comprehend. Try changing the initial and ending value to see the results.

Great! But what if we want to count by two – how do we do that. It seems like the A = A + 1 is implied.

The Basic language designers thought of that and have provided another keyword that can be added to the end of the FOR command to specify the value to be added each time around the loop – STEP.

The STEP keyword goes at the end of the FOR command – after the ending value. Let's replace line 10 with this new FOR command that has a STEP 2 on the end:

```
10 FOR A = 1 TO 10 STEP 2 Enter
```

Your program should now look like:

```
LIST
10 FOR A = 1 TO 10 STEP 2
20 PRINT A
30 NEXT A
Ready
```

Now RUN it:

```
RUN
1
3
5
7
9
Ready
```

The initial value, ending value and optional STEP value don't have to be numbers – they can also be numeric variables. And the STEP value can be negative to. Let's replace line 10 again to try this. Type:

```
10 FOR A = 10 TO 1 STEP -1 Enter
```

Your program should now look like:

```
LIST
10 FOR A = 10 TO 1 STEP -1
20 PRINT A
30 NEXT A
Ready
```

And when you RUN it:

```
RUN
10
9
8
7
6
5
4
3
2
1
Ready
```

There's a few more important things to know about FOR / NEXT. First, you shouldn't try to GOTO into the middle of a FOR / NEXT loop. When the Color LCD encounters the NEXT command without having seen the matching FOR first it gets confused and gives you an error. Here's an example of that error – we add a line at the beginning of the program to GOTO line 20 which is inside the FOR / NEXT loop:

```
LIST
5 GOTO 20
10 FOR A = 10 TO 1 STEP -1
20 PRINT A
30 NEXT A
Ready
RUN
 0
Nesting error in line 30 - NEXT without preceding FOR
```

The second thing to remember is that if you nest FOR / NEXT loops – one inside of another, you must close the inner loop before closing the outer loop. Here's the right way to nest loops:

```
LIST
10 FOR X = 1 TO 3
20 FOR Y = 3 TO 1 STEP -1
30 PRINT "X = ",X, " Y = ",Y
40 NEXT Y
50 NEXT X
Ready
RUN
X =  1 Y =  3
X =  1 Y =  2
X =  1 Y =  1
X =  2 Y =  3
X =  2 Y =  2
X =  2 Y =  1
X =  3 Y =  3
X =  3 Y =  2
X =  3 Y =  1
Ready
```

And here's the wrong way to nest loops:

```
LIST
10 FOR X = 1 TO 3
20 FOR Y = 3 TO 1 STEP -1
30 PRINT "X = ",X, " Y = ",Y
40 NEXT X
50 NEXT Y
Ready
RUN
X =  1 Y =  3
Nesting error in line 40 - NEXT var doesn't match FOR var
Ready
```

The third thing to remember is that you shouldn't try to GOTO out of a FOR / NEXT loop. While you won't receive an immediate error, the cleanup performed by the NEXT statement isn't performed and if you do it enough times

you will get an error when there isn't sufficient memory left for the display to remember more FOR / NEXT commands. Exiting a FOR / NEXT loop early is a fairly common programming requirement however so ACS Basic provides a system form of GOTO to jump out – EXITFOR. To try it, modify our existing program. First remove line 5 by typing:

```
5 Enter
```

And then add line 40 to indicate that we're done counting and provide a target line for the EXITFOR command:

```
40 PRINT "Done" Enter
```

And finally add a condition check for exiting the FOR / NEXT loop – let's say when the count variable is equal to 5 we want to leave the loop. Type:

```
15 IF A = 5 THEN EXITFOR 40 Enter
```

Your program should now look like:

```
LIST
10 FOR A = 10 TO 1 STEP -1
15 IF A = 5 THEN EXITFOR 40
20 PRINT A
30 NEXT A
40 PRINT "Done"
Ready
```

And when you RUN it:

```
RUN
10
9
8
7
6
Done
Ready
```

Counting Rules

1. A variable can appear on both sides of the assignment equal sign. The variable on the right hand side refers to its existing value and the left hand side variable will receive the new value.
2. You can implement a count sequence by assigning an initial value to a variable, advancing it by adding or subtracting to it then checking if it is at the ending value and looping back if it is not.
3. Basic provides a FOR / NEXT command with an optional STEP clause to simplify counting.
4. Nested FOR / NEXT loops must be closed from the inside out – inside loops first.
5. You can't jump into the middle of a FOR / NEXT loop – an error will result on the NEXT command.
6. You should only jump out of a FOR / NEXT loop using the system EXITFOR command.

Remembering your Programs

The Color LCD wouldn't be very useful if you always had to type in your programs every time you turned it on. The longer your programs are the more of a problem this would become.

The Color LCD has a slot for a micro SD memory card. You can SAVE your programs by name on the card and LOAD or RUN them later by referring to the same name.

Think of the micro SD card as a file drawer that holds many files. You can create a new file and put it in the drawer, or retrieve an existing file from the drawer. You can't retrieve a file that hasn't been created first. The Color LCD will keep a directory listing of what files are in the drawer (on the micro SD card).

Let's try it. Put a fresh card into the slot and ask for a directory of files. Type:

```
DIR Enter
```

On a fresh card you should see the following:

```
DIR
-----------------------------------------------
                                          0 files
                                          0 directories
Ready
```

The display is showing you that there are currently no files on the card. Now type in one of your earlier programs – remember to start with NEW Enter. Let's start with the simple FOR / NEXT program:

```
NEW
10 FOR A = 1 TO 10
20 PRINT A
30 NEXT A
```

You can RUN it to verify that it works as before. Now let's SAVE it in a file. Let's call it FORNEXT. Type:

```
SAVE FORNEXT Enter
```

Did it save it? Let's ask for a directory again:

```
DIR
FORNEXT.BAS                              43 A      02-26-2012 04:57:02 PM
-----------------------------------------------
                                          1 files
                                          0 directories
Ready
```

There it is. The display is telling us that it's 43 characters long, it was created on 2-26-2012 at 4:57PM and that there is one file on the card. What's the .BAS on the end of the file name? There can be many types of files in the drawer (on the card) and this is Basic's way of telling us that this file is a Basic program. Great! Now let's try to get it back.

First clear out the program and variables with NEW. Try a LIST and VARS to see that there's actually nothing in memory:

```
NEW
Ready
LIST
Ready
VARS
Ready
```

Now let's retrieve it. Type:

```
LOAD FORNEXT Enter
```

And then LIST it:

```
LOAD FORNEXT
Ready
LIST
10 FOR A = 1 TO 10
20 PRINT A
30 NEXT A
Ready
```

And there it is. You can RUN it to verify that it still works.

Modify it to count backwards by changing line 10 and adding the STEP keyword:

```
10 FOR A = 10 TO 1 STEP -1 Enter
```

You can LIST and RUN it. Then let's SAVE this as FORNEXTSTEP. Type:

```
SAVE FORNEXTSTEP Enter
```

Now let's ask for a directory again:

```
DIR
FORNEXT.BAS                              43 A      02-26-2012 04:57:02 PM
FORNEXTSTEP.BAS                          51 A      02-26-2012 05:12:56 PM
--------------------------------------------
                                          2 files
                                          0 directories
Ready
```

Both programs (files) are there. ACS Basic provides a shortcut for loading and running a program file – just type RUN followed by the file name. Basic will do the NEW, LOAD and RUN all in a single step:

```
RUN FORNEXT
1
2
3
4
5
6
7
8
9
10
Ready
RUN FORNEXTSTEP
10
9
8
7
6
5
4
3
2
1
Ready
```

Saving Rules

1. Programs can be filed onto a micro SD card installed in the Color LCD.
2. A directory of what files are on the card can be obtained by the DIR command.
3. Programs are saved to the card with the SAVE command.
4. Programs are retrieved from the card with the LOAD command.
5. Programs may be retrieved and executed with the RUN command.
6. ACS Basic remembers the last program file name used with LOAD, RUN or SAVE so a modified program can be saved into the same file using a SAVE command without a name.

Things to do with Numbers

So far we've seen that the Color LCD can add and multiply numbers – using numbers directly or numbers stored in variables. The display can also subtract and divide numbers. In computer terminology these actions are referred to as ***operators***. Let's try a few:

```
PRINT 4 - 2
2
Ready
PRINT 9 / 3
3
Ready
```

Here's a new operator that you probably haven't heard of or used before – remainder of division. In computer terminology this is referred to as a ***modulo operation***. The first number is divided by the second number and the remainder is returned. So if two numbers divide evenly, the modulo is zero – no remainder:

```
PRINT 10 % 5
0
Ready
```

However if the two numbers don't divide evenly, the modulo operator returns the remainder after the division that would be performed. So if we divide 5 by 4, the remainder or modulo would be 1:

```
PRINT 5 % 4
1
Ready
```

Operators usually go between two numbers or numeric variables. However there are some operators that go in front of a single number or variable. In computer terminology these are referred to as ***unary operators***. There are a couple of these, but the most common is a leading minus sign – referred to as negate:

```
A = 10
Ready
PRINT -A
-10
Ready
```

This is just a shorthand way of telling the Color LCD to subtract the number from zero.

Only Whole Numbers Please

Now let's try dividing two numbers that don't divide evenly – say 10 divided by 3:

```
PRINT 10 / 3
3
Ready
```

What happened? Shouldn't 10 divided by 3 equal 3 and 1/3? It should but this shows a limitation of ACS Basic – it only knows how to work with whole numbers – not decimals or fractions. So when it divides 10 by 3 it returns the whole number part and discards the fractional part. In computer terminology this is referred to as ***integer arithmetic***. While this can be a limitation for solving some problems most applications of the Color LCD can be performed only using integers – and there are some workarounds that we'll examine later. Remember, the modulo operator can return the remainder of the same division.

The Size of Numbers

So if ACS Basic can only work with whole numbers, how big can they be? What's the limit? This Basic works with what programmers refer to as short integers – they are 16 computer bits wide. A computer bit can only be on or off – when you have 16 of them across, with each one able to be on or off, the biggest number that they can represent is 65535 which is the number 2 raised to the 16^{th} power (65536) less one reserved for the zero = 65535.

Actually the computer in the Color LCD reserves 1 bit for a plus or minus indicator – a sign bit. So there are really only 15 bits available for the actual number. So the maximum positive number is +32767 and the maximum negative number is -32768.

Comparing Numbers

There are also operators for comparing two numbers. Numbers can be checked to see if they're the same or not or if one is larger or smaller than another. In computer terminology these checks are called ***comparison operators*** – two

numbers are compared with each other. The results of a comparison are either true or false. In ACS Basic, a true comparison results in a 1 and a false comparison results in a zero.

To check for equality (two numbers being the same) we use the equal operator – which is the equals sign:

```
PRINT 1 = 0
0
Ready
PRINT 2 = 2
1
Ready
```

So how do you test if two numbers are not equal? ACS Basic uses a less than followed immediately by a greater than (no space in-between) as the not equal operator. Notice how this check gives the opposite result of the equal check.

```
PRINT 1 <> 0
1
Ready
PRINT 2 <> 2
0
Ready
```

Of course we can also check for numbers being less than, less than or equal, greater than and greater than or equal:

```
PRINT 2 < 2
0
Ready
PRINT 2 <= 2
1
Ready
PRINT 4 > 4
0
Ready
PRINT 4 >= 4
1
Ready
```

Combining Numbers in Order

You don't have to only do a single operation on numbers at a time. You can combine them into a series of operations to achieve the result you want. In computer terminology this is referred to as an ***expression***.

Usually, when you perform a bunch of operations on numbers you do them in a left-to-right order. So if you want to add two numbers, and now double the result you might write:

```
PRINT 2 + 3 * 2
8
Ready
```

You would expect the result to be 2 plus 3 equals 5 times 2 equals 10 – right? How did the Color LCD come up with the number 8?

It turns out that in Basic, like most computer languages there is an order in which numeric operations are performed. In computer terminology this is referred to as ***operator precedence*** or ***operator priority***. If there wasn't an defined order then you could get different results each time or perhaps different results between different machines. Negation is performed first, then Multiplication, Division and Modulo, then Addition and Subtraction, then Comparisons are performed last. So the display does the 3 times 2 first, then it adds the 2 which gives 8 instead of 10.

What if you really want these operations done in the order that you wrote them down? Well it turns out that you can specify the order by grouping operations together using parenthesis. The Color LCD Basic will execute operations inside parenthesis first, then use that result to perform the next operation in the expression. So to get the result that you wanted above, you could write:

```
PRINT (2 + 3) * 2
10
Ready
```

So when in doubt, or when you really want things done in a certain order, use parenthesis to group operations together. The display will evaluate things from the inside out starting with the most nested set of parenthesis first.

Numeric Operator Rules

1. Numbers can be added, subtracted, multiplied, divided, remaindered, negated and compared.
2. Multiple operations can be performed sequentially to form a numeric expression.
3. Multiple operations are performed in a priority fashion from first to last: negation, multiplication and division, addition and subtraction, then comparison.
4. Multiple operations with the same priority are performed left to right.
5. Parenthesis can be used to change the order in which numeric expressions are evaluated.

Things to do with Strings

There are also operations that can be performed on strings. The most common of these are to combine two separate strings into a new single string by 'adding' one string onto the end of another. In computer terminology this is referred to as ***concatenation*** – the two strings are concatenated together:

```
PRINT "HELP" + "ME"
HELPME
Ready
Part1$ = "Help"
Ready
Part2$ = "Me"
Ready
PRINT Part1$ + " " + Part2$
Help Me
Ready
```

Comparing Strings

Like numbers you can also compare strings. The two strings are compared, a character at a time to determine if they are the same, less than or greater than each other:

```
PRINT "ONE" = "TWO"
0
Ready
PRINT "ONE" <> "TWO"
1
Ready
PRINT "ONE" > "TWO"
0
Ready
PRINT "ONE" < "TWO"
1
Ready
```

Now for Something at Random

By now we've learned a few different commands that the Color LCD Basic understands. Let's try something new. Type this line:

```
10 PRINT RND(10) Enter
```

And now RUN it. The display printed a random number between 0 and 9. RUN it a few more times:

```
10 PRINT RND(10)
Ready
RUN
8
Ready
RUN
7
Ready
RUN
5
Ready
RUN
1
Ready
```

Now make the program loop back to run continuously. Add line 20 to the program and RUN it. You will have to ESCape the program to stop it:

```
20 GOTO 10
LIST
10 PRINT RND(10)
20 GOTO 10
Ready
RUN
7
8
6
9
8
0
0
7
4
9
9
 ESC at line 10
Ready
```

What if we want to have random number from 0 to 100? Changed line 10 to this and RUN it:

```
10 PRINT "", RND(100);
LIST
10 PRINT "", RND(100);
20 GOTO 10
Ready
RUN
 59 51 31 73 82 62 38 92 78 58 71 84 28 94 46 43 2 59 26 80 32 41 44 43 12 31 30 84 18 58 4 80 11 3 56
39 14 60 0 42 33 95 95 9 56 80 91 16 54 7 86 37 12 25 45 37 82 67 29 95 26 9 23 62 74 57 80 6 16 83 85
68 64 39 22 45 37 81 50 56 93 56 58 4 70 17 0 28 81 99 61 22 36 74 27 9 19 12 9 38 32 87 41 18 35 12 70
28 40 60 22 38 83 23 58 23 17 30 75 95 11 46 12 67 7 26 52 7 39 1 70 67 69 39 53 0 63 28 25 94 39 27 86
94 7 20 25 52 94 88 45 38 99 25 92 72 25 45 15 67 5 48 19 66 71 20 51 74 12 36 89 24 6 4 60 80 29 55 65
46 48 30 29 14 86 80 7 84 50 26 74 53 78 44 3 9 19 94 8 24 42 99 92 58 31 73 27 46 23 55 49 29 82 27 75
49 97 54 75 64 88 62 49 8 65 52 73 36 9 74 60 35 62 37 46 63 1 88 46 50 64 5 96 21 43 68 19 77 51 37 71
57 25 55 65 21 84 89 77 72 72 76 68 84 49 6 93 82 42 93 57 75 39 87 94 70 94 61 97 32 45 79 39 92 24 10
49 20 8 7 39 7 16 78 2 16 15 90 53 19 10 11 76 82 99 70 27 83 97 94 29 34 78 35 69 22 70 26 29 84 90 97
97 11 16 3 42 83 77 52 86 39 48 91 80 37  ESC at line 10
Ready
```

It's a Function!

So the function of RND( ) is to produce random numbers. It takes a numeric value between the parentheses, computes a random number based upon the number that it's given and then takes on the value of that random number. It's kind of like a command and kind of like a variable at the same time. In computer terminology these

combination command / variables are referred to as ***functions***. Because they are part of the Basic language and don't have to be rewritten each time you want to use them they are referred to as ***built-in functions***.

Since functions act like a variable you can use them wherever you would read a variable – like in a PRINT command, an IF / THEN conditional check or in an expression. The difference between a function and a variable is that you can't assign a value to a function – you can only pass arguments to it and then use the value that it assumes as a result.

In computer terminology this is referred to as ***calling a function that takes an argument and returns a value***. It's like a variable, but you don't assign values to it – instead you pass it one or more arguments between the parenthesis and it acts like a variable whose value changes based upon the arguments.

There are other functions that are very useful when writing Basic programs. Some take no arguments but return a value – either numeric or string. Some take one or more numeric arguments and return a numeric value. Some take string arguments and return a numeric value. Some take both string and numeric arguments and return a value.

So how do you know what type of value a built-in function will return? Just like a Basic variable – it's all in the name. If a built-in function returns a string value, the function name ends with a dollar sign – otherwise it returns a numeric value. This makes sense because functions can be used in place of variables.

Function Rules

1. Functions behave like read-only variables that can supply different values or behavior in your programs depending upon what they are pre-defined to do and what arguments that they may require to do it.
2. When calling a function, the function name must be immediately followed by the opening parenthesis surrounding the function's arguments.
3. The type of a function is identified by the name, just like a variable.

Some Funny Characters

Your communications device – whether it is a PC or PS/2 keyboard or even the pop-up touch keypad has a limited set of characters. Your program may require some special characters or symbols be displayed – like a degree symbol after a temperature for example. The Color LCD can display these characters that don't appear on the keyboard, but it takes a couple tricks.

The first trick is the understanding that each displayed character is actually based upon a number. Back in the 60's a standards committee got together and hashed out a definition of what number represents what character. It started with the old telegraphic codes for characters and evolved to support the newly designed teleprinters. In computer terminology this is called ***A.S.C.I.I. – which is the abbreviation for American Standard Code for Information Interchange***. It defines 128 characters and control codes, each of which can be uniquely represented by a seven bit number.

There's a chart of these numbers and their representative characters at http://www.asciitable.com . Now when we want to show a certain character we just have to the single 7-bit number to be sent to the display. This means we need a function that takes in a decimal number and converts it to a single number representing the string character based upon this ASCII standard. ACS Basic has just such a function built-in.

The CHR$( ) function takes a decimal number argument and returns a single character string where the character is the ASCII character of the decimal number. This character can then be sent to the display by PRINTing it. Let's try it:

```
PRINT CHR$(65)
A
Ready
PRINT CHR$(48)
0
Ready
```

So how do we display characters that aren't in the ASCII standard? It turns out that there is another standard call Unicode which defines how to combine multiple non-ASCII codes into a single extended character. Remember that ASCII only defines 7-bit codes, 0 – 127. Since computers work with 8-bit codes, 0 – 255, that leaves codes 128 – 255 available. However the Unicode designers didn't want to limit themselves to just 128 more characters – multiple languages required many more. So they came up with an expandable scheme using multiple prefix characters that can be combined and decoded to represent many more extended characters.

Sound complicated – and it can be – if you have to do the encoding and decoding. However the Color LCD only provides display support for what is known as the DOS – United States character set. There is a table of these supported characters at the end of this manual. To display them you just have to send the multiple character sequence underneath the character. The definition of what values represent what extended characters was also defined starting in the 60's and is loosely known as the ANSI code standard. ANSI stands for American National Standards Institute.

So let's try showing that degree character. From the table, it looks like the two codes are 194 and 176 – remember to separate the two function calls with a semicolon – if you use a comma instead it won't work because a space character (32) will get inserted between them:

```
print chr$(194);chr$(176)
°
Ready
```

And there it is. You can try some others from the table – some take two codes and some three. Using Basic PRINT commands to display characters is referred to as ANSI operation.

Don't Get Boxed In

If you look at the Extended Characters table at the end of the manual, there are some that can be used for line drawing. Let's try and draw a simple box. We need the four corners, the lines across the top and bottom and the lines on the side. Try typing this short program in – don't forget to NEW first:

```
10000 REM Draw a box using ANSI characters
10005 PRINT CHR$(226); CHR$(148); CHR$(140);
10010 FOR I=1 TO 10
10015 PRINT CHR$(226); CHR$(148); CHR$(128);
10020 NEXT I
10025 PRINT CHR$(226); CHR$(148); CHR$(144)
10030 PRINT CHR$(226); CHR$(148); CHR$(130);
10035 FOR I = 1 TO 10
10040 PRINT " ";
10045 NEXT I
10050 PRINT CHR$(226); CHR$(148); CHR$(130)
10055 PRINT CHR$(226); CHR$(148); CHR$(148);
10060 FOR I=1 TO 10
10065 PRINT CHR$(226); CHR$(148); CHR$(128);
10070 NEXT I
10075 PRINT CHR$(226); CHR$(148); CHR$(152)
```

And now RUN it:

```
run
┌──────┐
└──────┘
Ready

save ansibox
Ready
```

If it works as shown then you can save it for later.

Now you're probably asking yourself a couple of questions: First, what is the REM command on the first line? We're glad you asked. Second, why are the line numbers so large? We'll get to that shortly.

A Casual Remark

The REM command allows you to put notes (REMarks) into your programs. The REM command actually does nothing - when ACS Basic 'sees' the REM command it skips over the rest of the line. In computer terminology the use of the REM command is referred to as ***commenting your code***. It serves a couple of purposes – reminding yourself about what you were trying to do with this code, and documenting what you hope that it does as an aid for others. While it doesn't seem important now with these tiny programs, it will become increasingly important when the programs get larger and you have many more of them to keep track of. It's considered good practice.

The large line numbers allow us to come back later and put some lower-numbered lines before these. In this example they're going to let us save some typing.

Character Rules

1. Characters are actually a displayed version of a single number.
2. The first 128 characters (numbers 0 – 127) have been agreed upon and are referred to as the ASCII character set. Refer to http://www.asciitable.com
3. There is a built-in function, CHR$( ) that can convert a numeric argument into a character.
4. Additional extended characters may be displayed using multiple character prefix codes.
5. Using Basic PRINT commands on the display is known as ANSI operation.

Don't Repeat Yourself

Suppose that you want to draw two boxes, one above the other. You could type the same thing in again, duplicating all of these lines. Your programs would tend to get quite large – and, you might run out of line numbers. What you have now is a box-drawing routine. Suppose you could just call this routine whenever you wanted to draw a box.

Good News! You can. There is a routine calling command in most computer languages – including ACS Basic. In computer terminology these common routines are referred to as ***subroutines***. So how do you get to this part of your program from somewhere else? And how do you get back? The new command pair is GOSUB / RETURN. And they are a pair – you can't have one without the other. The computer terminology is ***calling into a subroutine*** and ***returning from a subroutine*** – call in and return back right after where you called from.

Let's add some additional lines to the program:

```
10 print "Here's a box:"
20 gosub 10000
30 print "And here's another:"
40 gosub 10000
50 end
```

And don't forget the last line that will turn the box drawing lines into a subroutine:

```
10080 return
```

Your program should now look like this:

```
list
10 PRINT "Here's a box:"
20 GOSUB 10000
30 PRINT "and here's another:"
40 GOSUB 10000
50 END
10000 REM Draw a box using ANSI characters
10005 PRINT CHR$(226); CHR$(148); CHR$(140);
10010 FOR I=1 TO 10
10015 PRINT CHR$(226); CHR$(148); CHR$(128);
10020 NEXT I
10025 PRINT CHR$(226); CHR$(148); CHR$(144)
10030 PRINT CHR$(226); CHR$(148); CHR$(130);
10035 FOR I = 1 TO 10
10040 PRINT " ";
10045 NEXT I
10050 PRINT CHR$(226); CHR$(148); CHR$(130)
10055 PRINT CHR$(226); CHR$(148); CHR$(148);
10060 FOR I=1 TO 10
10065 PRINT CHR$(226); CHR$(148); CHR$(128);
10070 NEXT I
10075 PRINT CHR$(226); CHR$(148); CHR$(152)
10080 RETURN
Ready
```

And when you run it:

```
run
Here's a box:
┌──────┐
└──────┘
and here's another:
┌──────┐
└──────┘
Ready
```

If you change the GOSUB to a GOTO you will get an error when your program executes the RETURN command – it doesn't know the way back that is remembered by the GOSUB.

Subroutines are used to replace common or duplicate code. If you look at our program there's another common piece of code that could be made into a subroutine – the PRINTing of the Unicode prefix for the box drawing extended characters: PRINT CHR$(225); CHR$(148);

Let's make this repetitive code into a separate subroutine – it could go above or below, we'll put it below:

```
10100 REM Print the Unicode prefix characters
10105 PRINT CHR$(226); CHR$(148);
10110 RETURN
```

```
list
10 PRINT "Here's a box:"
20 GOSUB 10000
30 PRINT "and here's another:"
40 GOSUB 10000
50 END
10000 REM Draw a box using ANSI characters
10005 PRINT CHR$(226); CHR$(148); CHR$(140);
10010 FOR I=1 TO 10
10015 PRINT CHR$(226); CHR$(148); CHR$(128);
10020 NEXT I
10025 PRINT CHR$(226); CHR$(148); CHR$(144)
10030 PRINT CHR$(226); CHR$(148); CHR$(130);
10035 FOR I = 1 TO 10
10040 PRINT " ";
10045 NEXT I
10050 PRINT CHR$(226); CHR$(148); CHR$(130)
10055 PRINT CHR$(226); CHR$(148); CHR$(148);
10060 FOR I=1 TO 10
10065 PRINT CHR$(226); CHR$(148); CHR$(128);
10070 NEXT I
10075 PRINT CHR$(226); CHR$(148); CHR$(152)
10080 RETURN
10100 REM Print the Unicode prefix characters
10105 PRINT CHR$(226); CHR$(148);
10110 RETURN
Ready
```

And now we have to change lines 10005, 10015, 10025, 10030, 10050 10055, 10065 and 10075. You could type these lines over, but as we'll see soon, ACS Basic has a shortcut – the EDIT command.

Rules for Subroutines

1. Any block of code can be turned into a subroutine by adding a RETURN command as the last line and then calling the code using the GOSUB command.
2. GOSUB commands must be paired with RETURN commands – you can't GOTO in or out of a subroutine.
3. Subroutines can be nested – code inside a subroutine can call another subroutine.

Making Changes

Type:

```
EDIT 10005
```

Notice how Basic prints out the line, but stays at the end – it doesn't show the Ready prompt. The cursor is blinking at the end of the line. It's waiting for you to modify the line and tell it when you're done.

```
edit 10005

10005 PRINT CHR$(226); CHR$(148); CHR$(140); _
```

You can move your blinking cursor left and right with the keyboard left and right arrow keys ←. Some communication devices will also allow you to Home home to the beginning of the line or End end to the end of the line. You can delete characters left of the cursor using the backspace key backspace. If you want to quit editing without saving your changes use the double ESCape esc esc key. When you want to stop editing and save your changes press the enter key Enter↵.

One thing to remember about EDITing – you're always in 'insert' mode. Any printable character that you type will be inserted into the line wherever the cursor is blinking. If you make a mistake, you can use the backspace key and retype it, or use the arrow keys to move after it, backspace and retype.

Use the left arrow key to move the cursor from the end of the line to the C in the last CHR$(140);. Now press the backspace key to remove characters until the space after the PRINT. Again use the left arrow key to move the cursor to the P in the PRINT. The type in GOSUB 10100: - the colon is important, it allows you to group multiple commands on the same line. When you're done making these changes the line should look like:

```
10005 GOSUB 10100 : PRINT CHR$(140);
```

If it doesn't look like this use the arrow keys, backspace and typing to correct it. When it does look like this press Enter. The line should be accepted as if you had typed it in again instead of editing. You can look at it using the LIST command with the line number:

```
list 10005
10005 GOSUB 10100 : PRINT CHR$(140);
Ready
```

Try running the program. It should work the same as it did before the change.

Edit the other lines to make the same change. Once you get the hang of using the EDIT command you'll probably find it much easier than typing the complete line over again, and you'll tend to make fewer mistakes.

```
list
10 PRINT "Here's a box:"
20 GOSUB 10000
30 PRINT "and here's another:"
40 GOSUB 10000
50 END
10000 REM Draw a box using ANSI characters
10005 GOSUB 10100 : PRINT CHR$(140);
10010 FOR I=1 TO 10
10015 GOSUB 10100 : PRINT CHR$(128);
10020 NEXT I
10025 GOSUB 10100 : PRINT CHR$(144)
10030 GOSUB 10100 : PRINT CHR$(130);
10035 FOR I = 1 TO 10
10040 PRINT " ";
10045 NEXT I
10050 GOSUB 10100 : PRINT CHR$(130)
10055 GOSUB 10100 : PRINT CHR$(148);
10060 FOR I=1 TO 10
10065 GOSUB 10100 : PRINT CHR$(128);
10070 NEXT I
10075 GOSUB 10100 : PRINT CHR$(152)
10080 RETURN
10100 REM Print the Unicode prefix characters
10105 PRINT CHR$(226); CHR$(148);
10110 RETURN
Ready
run
Here's a box:
┌──────────┐
```

```
┌──────────┐
└──────────┘
and here's another:
┌──────────┐
└──────────┘
Ready
```

And finally, now that you know you can have multiple statements on a line, you can shorten this up some more while still keeping it readable:

```
list
10 PRINT "Here's a box:" : GOSUB 10000
30 PRINT "and here's another:" : GOSUB 10000
50 END
10000 REM Draw a box using ANSI characters
10005 GOSUB 10100 : PRINT CHR$(140);
10010 FOR I = 1 TO 10 : GOSUB 10100 : PRINT CHR$(128); : NEXT I
10025 GOSUB 10100 : PRINT CHR$(144)
10030 GOSUB 10100 : PRINT CHR$(130);
10035 FOR I = 1 TO 10 : PRINT " "; : NEXT I
10050 GOSUB 10100 : PRINT CHR$(130)
10055 GOSUB 10100 : PRINT CHR$(148);
10060 FOR I=1 TO 10 : GOSUB 10100 : PRINT CHR$(128); : NEXT I
10075 GOSUB 10100 : PRINT CHR$(152)
10080 RETURN
10100 REM Print the Unicode prefix characters
10105 PRINT CHR$(226); CHR$(148); : RETURN
Ready
```

Rules for Editing

1. You can modify program lines in-place using the EDIT command.
2. While EDITing a program line, the arrow keys move the blinking cursor left and right and the backspace key deletes the character to the left.
3. While EDITing a program line any other character that you type will be entered into the line where the blinking cursor is – you are always in 'insert mode'.
4. You can discard your changes by ESCaping – pressing the ESC key twice in a row.
5. You can accept your changes by pressing enter – you don't have to be at the end of the line.

There's a System

So far, we've only defined our own variables – numeric and string, simply by using them in our programs to remember values. We've used commands and operators to access, modify and compare their contents. And we've used built-in functions like read-only variables to extend our program operation with built-in functionality. What's next?

Just like the built-in functions, ACS Basic has some built-in variables to access and modify values used by the Color LCD 'system'. These are called System Variables and they use a special naming so that they don't interfere with your program variables. So what can these System Variables do for you?

How about timing? Let's try to make a simple metronome application. Type NEW and enter the following small program:

```
10 REM Metronome
15 t = 0 : INPUT "Enter tempo (1 - 32766) :",tempo
20 IF tempo < 1 OR tempo > 32766 THEN GOTO 15
25 FOR i = 1 TO tempo : d = d + 1 : NEXT i
30 IF t = 0 THEN PRINT "Tick" ELSE PRINT "Tock"
35 IF t = 0 THEN t = 1 ELSE t = 0
40 GOTO 25
Ready
```

Let's take a moment and see what this program is doing. Line 10 is a REMark – a comment – telling us what this program is.

Line 15 initializes the tick/tock variable – this isn't really necessary since variables are set to 0 the first time they're used, but it's good practice to start with a known value. The program user is then prompted to enter a number for the tempo – notice that the INPUT command can have an optional prompt string that it will display before waiting for the user to enter a value and press enter.

Line 20 checks the tempo that the user entered and, if it's not within range, requests that the user enter a different value by looping back to line 15. It's always a good idea to validate user input to your programs. Notice that it performs two comparisons on the tempo value and then combines them logically with the OR logical operator – IF the first condition OR the second condition is True THEN loop back to line 15.

Lin 25 counts from one to the tempo value – it does nothing but waste time. The amount of time that must pass before the FOR / NEXT counting loop ends is dependent upon the tempo value entered. The d=d+1 statement is there solely to slow the loop down so reasonable tempo values have an effect.

Line 30 prints Tick or Tock depending upon the tick/tock variable t. Line 35 toggles the tick/tock variable t between zero and one.

Line 40 loops back to the delay loop.

Try running the program and entering different values for the tempo – a value of 4000 seems to be close to 60 beats per minute – once a second. You will have to ESCape the program to try another tempo:

```
run
Enter tempo (1 - 32766) :4000
Tick
Tock
Tick
Tock
Tick
Tock
Tick
Tock
Tick
 ESC at line 25
Ready
```

So how can we improve this program? It sure would be more useful to just enter the beats per minute instead of an arbitrary number. And this program kind of works backwards – a higher tempo value should result in a faster beats per minute – not slower.

We could try different equations to compute a delay loop count that corresponds to the requested tempo value but that would take a lot of trial and error to get the correct calculation that would relate the two values. A better idea would be to use some kind of timer that we could control.

System Timers

The Color LCD system has such a timer – in fact, there are ten of them. How do you access them and how do they work?

In ACS Basic, a system variable is identified by preceding the name with the '@' character. To access the first timer you would write:

```
@TIMER[0] = value : REM sets timer 0

value = @TIMER[0] : REM gets timer 0
```

There is an array of ten timers: numbered 0 – 9. You might have guessed that the zero in brackets is telling Basic that you want timer number 0. The brackets [ ] indicate that you are selecting a single timer – the one identified by the number in-between. In computer terminology this is referred to as ***indexing into an array***.

@TIMER[10]	**values**
@TIMER[0]	
@TIMER[1]	
@TIMER[2]	
@TIMER[3]	
@TIMER[4]	
@TIMER[5]	
@TIMER[6]	
@TIMER[7]	
@TIMER[8]	
@TIMER[9]	

So how do these timers work? Fifty times per second, the Color LCD checks these ten timers. If any of them are not equal to zero then the display subtracts one from it. In computer terminology this is referred to as ***decrementing a non-zero timer***. So you start the timer by setting it to a non-zero value, then you can 'monitor' the timer by checking to see if it is at zero. Since it counts down by 50 times per second, to set the timer for one second you would set it to fifty. Cool.

So how do we set a timer count for beats per minute? We can calculate this given the counts per second and the seconds per minute to get the counts per beat:

$$\frac{\left(50\frac{counts}{second}\times 60\frac{seconds}{minute}\right)}{\frac{beats}{minute}} = 3000\frac{counts}{beats}$$

OK. Divide 3000 by the desired beats per minute and use that to set the timer. Then we can loop for the timer to be zero for our delay.

As for validating the user input, we can't divide by zero – it's an error so we have to be greater than that, and dividing 3000 by anything larger than 3000 will result in a zero – timer won't run at all. Reasonable numbers are probably greater than 30 bpm and less than 300 bpm. Let's change the program:

```
10 REM Metronome
15 t = 0 : INPUT "Enter tempo beats per minute (30 - 300) :",tempo
20 IF tempo < 30 OR tempo > 300 THEN GOTO 15
25 @TIMER[0] = 3000 / tempo
27 IF @TIMER[0] > 0 THEN GOTO 27
30 IF t = 0 THEN PRINT "Tick" ELSE PRINT "Tock"
35 IF t = 0 THEN t = 1 ELSE t = 0
40 GOTO 25
```

And you can run it and try different tempo values.

Rules for System Variables

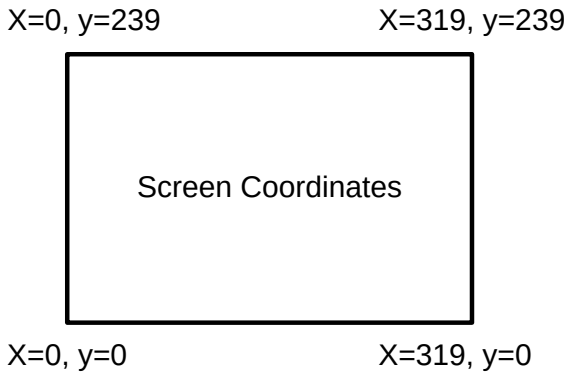
1. System variables access and control Color LCD system functions.
2. System variable names are prefixed with an '@' character.
3. System variables can have different meaning between if they are read versus written.

4. Some system variables are read-only.
5. Some system variables are implemented as an array and require an index for selection.

Enough Text – Let's Draw Something

Up to now we have been PRINTing in ANSI operation. That's nice, but what about some graphics. The Color LCD and ACS Basic provide several commands to draw graphics on the screen.

The graphic drawing commands use pairs of numbers to identify where you want to draw on the display. In computer terminology these are referred to as ***screen coordinates***. The first number of the pair is the X coordinate and identifies a horizontal starting point that ranges from zero to one less than the width of the display (0 – 319). The second number of the pair is the Y coordinate and identifies a vertical starting point that ranges from zero to one less than the height of the display (0 – 239). The X and Y coordinates for drawing start at **0, 0** at the lower left corner of the display and range to 319, 239 at the upper right corner of the display as shown in this diagram:



Drawing is clipped at the coordinate boundaries of the display – commands that specify coordinates outside of these boundaries will not affect the display when either coordinate exceeds these values.

Pixels

The screen is divided up into thousands of dots arranged in columns (0 – 319) and rows (0 – 239) that can be individually colored with one of 65536 colors. In computer terminology these dots are referred to as ***pixels***. The pixel color is selected by specifying the amount of three pure color components that are added to form the desired color – the amount of Red, the amount of Green and the amount of Blue. In computer terminology this is referred to as an ***additive RGB color model***.

The Color LCD supports 32 Red levels (0 – 31), 64 Green levels (0 – 63) and 32 Blue levels (0 – 31) for each pixel. There are more green levels than red or blue because the human eye is most sensitive to changes in green. Thirty two unique values can be determined using 5 binary bits, and sixty three unique values can be specified using 6 binary bits – so this form of RGB color encoding is known as RGB565. Hey – the total number of bits is 16 – the same number in our integer arithmetic! So, since the colors are additive, black must be equal to zero, and white must be equal to 65535 (largest 16-bit number).

The ACS Basic drawing commands allow your program to control the colors of one or more pixels at a time, depending upon the command, to draw graphic objects. The command to draw a single pixel is the simplest command – this table shows how the command is constructed and what the command arguments are (don't type this in directly, it's a description showing you how to construct this command):

DRAW.PIXEL x,y,color	
Sets the pixel at x,y on the current drawing @SURFACE to color	x = screen x coordinate (0 – 319) y = screen y coordinate (0 – 240) color = RGB565 pixel color

Let's use this description to construct a command that draws a white pixel at the center of the screen – don't worry about the @SURFACE system variable for now – we need to specify the x and y coordinates and the desired pixel color:

```
draw.pixel 160,120,65535
```

The white pixel is probably hard to see amongst the text on the screen – you could draw a red pixel that might be easier to see but how to you specify the red color? There's a built-in function for that.

The RGB(r, g, b) function takes three arguments, red level r (0 – 255), green level g (0 – 255) and blue level b (0 – 255) and does the math to combine them into a 16-bit integer – which is its return value. So let's use this to draw a red pixel:

```
draw.pixel 160,120,rgb(255,0,0)
```

Kind of hard to see – the individual pixels are kind of small and there's a lot of clutter on the screen. Let's use another system variable to stop showing the program text and PRINT output on the small screen – they will still show on your connected communications device. The ANSI operating mode can be turned off by setting the @ANSI.ENABLE system variable to zero:

```
@ANSI.ENABLE=0
```

Now as you type, or PRINT, the output doesn't affect the Color LCD screen. As a default, so nobody wonders where their PRINT output or Ready prompt went, the @ANSI.ENABLE is set to one whenever a program is run or stops. So if you don't want ANSI output on the Color LCD screen while your program is running you will have to turn it off at the beginning of your program, and keep your program running.

Clearing The Screen

One last thing – how do we clear the screen so we can see the pixel? Turns out that there's a command for that to – in computer terminology this is referred to a ***filling the screen***. Here's the command format:

DRAW.FILL x, y, width, height, color	
Sets the width by height pixels starting at x, y on the current drawing @SURFACE to color	x = screen x coordinate (0 – 319) y = screen y coordinate (0 – 240) width = number of pixels wide to fill height = number of pixels high to fill color = RGB565 fill pixels color

So try it:

```
draw.fill 0, 0, 320, 240, RGB(0, 0, 0)
```

You can experiment with different positions, widths, heights and colors. So now we have enough for a simple graphics program:

```
10 REM Draw a red pixel at the center of the screen
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.PIXEL 160,120,RGB(255,0,0)
30 GOTO 30
```

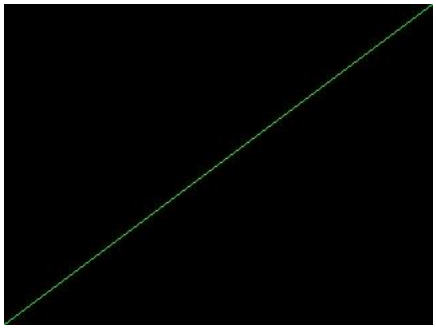
Drawing Lines

How about drawing lines? Let's try drawing a green line diagonally from one corner of the screen to the other. Here's the command format:

DRAW.LINE sx, sy, ex, ey, color	
Draws a line from sx, sy to ex, ey on the current drawing @SURFACE using color	sx = starting x coordinate (0 – 319) sy = starting y coordinate (0 – 240) ex = ending x coordinate (0 – 319) ey = ending y coordinate (0 – 240) color = RGB565 line pixels color

Here's the program:

```
10 REM Draw a green line from lower-left to upper-right
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.LINE 0,0,319,239,RGB(0,255,0)
30 GOTO 30
```



Drawing Boxes

How about drawing boxes. You could compute and draw each line making up the box, or have ACS Basic draw it for you if you provide the locations of two diagonal corners. Here's the command format:

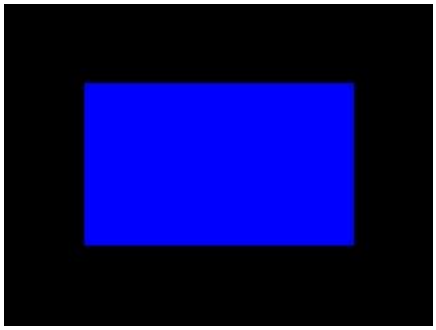
DRAW.BOX x1,y1,x2,y2,color	
Draws a box from diagonal corners x1,y1 to x2,y2 on the current drawing @SURFACE using color	x1 = corner 1 x coordinate (0 – 319) y1 = corner 1 y coordinate (0 – 240) x2 = corner 2 x coordinate (0 – 319) y2 = corner 2 y coordinate (0 – 240) color = RGB565 box pixels color

Here's the program:

```
10 REM Draw a blue box around the screen edge
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.BOX 0,0,319,239,RGB(0,0,255)
30 GOTO 30
```

And if you want a filled box:

```
10 REM Draw a blue box around the screen edge
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.BOX.FILLED 60,60,260,180,RGB(0,0,255)
30 GOTO 30
```



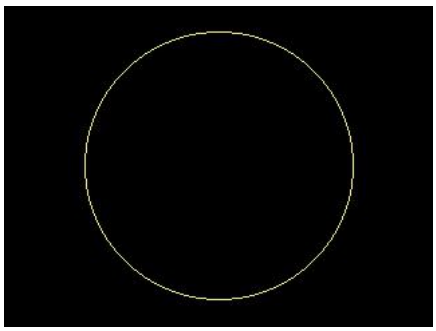
Drawing Circles

Drawing a circle. Here's the command format:

DRAW.CIRCLE x,y,r,color	
Draws a circle of radius r centered at x, y on the current drawing @SURFACE using color	x = center x coordinate (0 – 319) y = center y coordinate (0 – 240) r = circle radius(0 – 319) color = RGB565 circle pixels color

And here's a program to draw a yellow circle centered on the screen:

```
10 REM Draw a blue box around the screen edge
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.CIRCLE 160,120,100,RGB(255,255,0)
30 GOTO 30
```



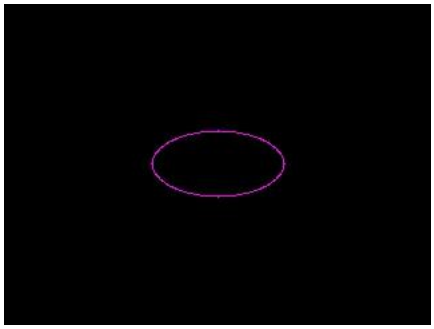
Drawing Ellipses

Drawing an Ellipse. Here's the command format:

DRAW.ELLIPSE x, y, width, height, color	
Draws a width by height ellipse centered at x, y on the current drawing @SURFACE to color	x = center x coordinate (0 – 319) y = center y coordinate (0 – 240) width = major axis width height = minor axis width color = RGB565 ellipse pixels color

And here's a program to draw a magenta ellipse centered on the screen:

```
10 REM Draw a blue box around the screen edge
15 @ANSI.ENABLE=0
20 DRAW.FILL 0,0,320,240,RGB(0,0,0)
25 DRAW.ELLIPSE 160,120,100,50,RGB(255,0,255)
30 GOTO 30
```



If you want a filled ellipse change line 25:

```
25 DRAW.ELLIPSE.FILLED 160,120,100,50,RGB(255,0,255)
```

Drawing Polygons

A polygon is a flat shape consisting of straight lines that are joined to form a closed chain. A triangle is just a 3-sided polygon, a box is a 4-sided polygon with right angles between the sides. An N-sided polygon requires N coordinate pairs for its vertices.

How can we format a polygon draw command that can take a variable number of coordinates? The answer is to use an array of numbers to store each coordinate and just provide the array names to the polygon command.

Array variables are just a table of numbers or strings. In order to use an array you have to tell Basic how big of a table that you want. The Color LCD then sets aside the correct amount of memory for that variable to hold the number of values that you require. In computer terminology this is referred to as ***dimensioning an array***. Basic provides a DIMension command for this purpose:

```
30 DIM x[3],y[3]
```

When you access the individual values in this array you specify an index into the table to select which value that you want. The index follows the variable name and is enclosed in brackets [ ]. Here's a conceptual picture of what a 5 element numeric array looks like. Notice that there are 5 elements, numbered 0 – 4:

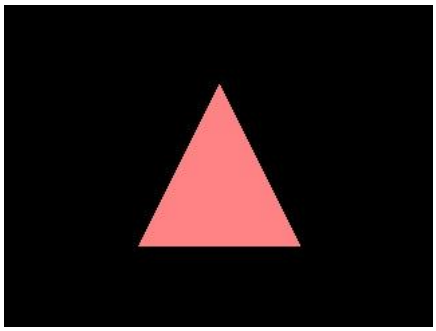
DIM Variable[5]	**values**
Variable[0]	
Variable[1]	
Variable[2]	
Variable[3]	
Variable[4]	

Since each array variable holds a single set of values, to draw a polygon you will need two arrays: one for the X coordinates of each vertex and one for the Y coordinates. Your program 'fills' these arrays with the coordinates for each point – prior to calling the DRAW.POLYGON command. The command looks at the dimensioned size of these coordinate arrays to determine how many sides (and vertices) that the polygon should be drawn with.

So let's draw a 3-sided polygon – a triangle – centered on the screen. We need X and Y coordinate arrays that each hold 3 values. Here's the program:

```
10 REM Draw a triangle
20 @ANSI.ENABLE=0
30 DIM x[3],y[3] : REM Allocate coordinate arrays
40 DRAW.FILL 0,0,320,240,RGB(0,0,0)
50 REM Load x & y coordinates
60 x[0]=100:y[0]=60:x[1]=220:y[1]=60:x[2]=160:y[2]=180
70 DRAW.POLYGON x,y,RGB(255,128,128)
80 GOTO 80
```

And you can also fill it in – change the DRAW.POLYGON command to DRAW.POLYGON.FILLED.



Drawing Text

Let's say that we need to put text on the screen along with our graphics. You could leave the @ANSI.ENABLE system variable set to one, and use PRINT commands. How do you control where the text appears on the screen?

The @ANSI command has a few additional modifiers – two of which allow you to read the current ANSI row and column values, or set them before printing: @ANSI.ROW and @ANSI.COL. The ANSI rows and columns are numbered like this starting in the upper left of the screen:

	Col 0	Col 1	Col 2	…	Col 42	Col43	Col 44
Row 0							
Row 1				…			
Row 2							
…				…			
Row 17							
Row 18				…			
Row 19							

Try it out – PRINT Hello in the middle of the screen:

```
@ANSI.ROW = 10 : @ANSI.COL = 17 : PRINT "Hello!"
```

While this does work – there are a few problems. The cursor appears, blinking, on the screen – which you may not want. You can turn this off with another @ANSI command:

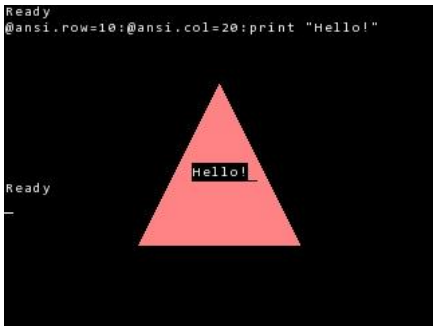
```
@ANSI.CURSOR = 0 : REM Turn off ANSI cursor
```

And, if you PRINT on the bottom line of the screen without a trailing semi-colon – or if the text wraps to the next line the screen will scroll up. You can turn these features off with another couple @ANSI commands:

```
@ANSI.WRAP = 0 : REM Turn off ANSI line wrap

@ANSI.SCROLL = 0 : REM Turn off ANSI screen scrolling
```

While this method of drawing text can be made to work, the positioning is coarse, the characters are always white on black, and you are stuck with the character height and style that ANSI operation uses. We'll examine an alternative text display method next which uses another DRAW command along with some additional system commands to control the text appearance.



Drawing Text with Style

The shape, appearance and size of drawn text characters specify the text's style. In computer terminology the style of text is referred to as a ***font***. The Color LCD and ACS Basic provide support for up to 32 different fonts to be in use at a time. Each of the 32 fonts can be configured by your program to change the text color, relative position and appearance. The entries in this font table are accessed through system variables. The individual character shapes and their size are obtained from another table in memory by their name – these are the actual embedded fonts. The two pieces of information: the embedded font to use and how it is colored and positioned are selected as an entry in the font table used to draw the desired text. In computer terminology this is referred to as ***rendering text***.

The embedded fonts must be loaded into the display's memory in order to be used for drawing text. They are stored in a collection with other items where they can be quickly accessed by their name.

It's a Matter of Resources

In the Color LCD there is a collection of fonts and other objects that the Basic can draw with – they are collectively known as Resources. The Color LCD looks for resources to load in two places when it starts-up: if there is a micro SD card installed it tries to load a binary file named Resource.bin, and if that fails it tries to load the resources from the on-board flash memory chip.

You can see this process happen when the Color LCD is powered on or reset – the status of the resource search and load is displayed on the top few lines of the screen.

You can list the resources that are currently loaded, the command is RESOURCES.LIST. Here is what the list would look like if no additional resources could be found and loaded at power-up:

```
resources.list
AcsAnsiFont.efnt                12,604 builtin
AcsDefaultFont.efnt             27,940 builtin
ButtonK.bmp                      1,610 builtin
ButtonK2.bmp                     2,050 builtin
ButtonK4.bmp                     3,018 builtin
ButtonM.bmp                      2,618 builtin
Ready
```

There are a few resources that are built-in: they are required to allow the status display, Configuration Settings screen and other features to operate if no additional resources can be found. The files with the .EFNT extension are 'embedded font files'. They contain the information about the size and shape of the text characters for drawing purposes. The AcsAnsiFont.efnt file is used for PRINTing ANSI text, the AcsDefaultFont.efnt is used for displaying the power-up status messages and labeling the keys on the Configuration Settings keypad.

There is a Windows utility that can be used to generate these embedded font files from existing computer font files – you select the computer font, what size to make it, what characters to include in the font and what name to give the generated .EFNT file and the utility generates the file.

How do you get your embedded font files into the Color LCD resources? You can then place the embedded font file on the micro SD card and load it into the resources manually or in your program using the RESOURCES.ADD command:

```
resources.add ComicSansBold14.efnt
Ready
resources.list
ComicSansBold14.efnt            25,666
AcsAnsiFont.efnt                12,604 builtin
AcsDefaultFont.efnt             27,940 builtin
ButtonK.bmp                      1,610 builtin
ButtonK2.bmp                     2,050 builtin
ButtonK4.bmp                     3,018 builtin
ButtonM.bmp                      2,618 builtin
Ready
```

So there are at least two embedded font files to work with that are built-in. How can we use these to draw text on the screen? Let's look using the FONTS commands.

It's a Table of Fonts

Just like with the resources, there is a FONTS.LIST command. Try it:

```
fonts.list
F#, "Resource Name                ", BCOLOR         , FCOLOR         , SPACEX, SPACEY, ALIGNH, ALIGNV, BTRANS, FTRANS
 0, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(128,128,128),      0,      0,      1,      1,      1,      0
 1, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
 2, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(128,128,128),      0,      0,      1,      1,      1,      0
 3, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
 4, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(128,128,128),      0,      0,      1,      1,      1,      0
 5, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
 6, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
 7, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
 8, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
 9, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
10, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
11, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
12, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
13, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
14, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
15, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
16, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
17, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
18, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
19, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
20, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
21, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
22, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
23, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
24, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
25, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
26, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
27, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
28, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
29, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
30, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(248,252,248),      0,      0,      1,      1,      1,      0
31, "AcsDefaultFont.efnt          ", RGB(  0,  0,  0), RGB(  0,  0,  0),      0,      0,      1,      1,      1,      0
Ready
```

What are all of these numbers? The first column is the 'font number' – the index into the font table. In Basic you can treat this table as an array using an index to access individual rows.

The second column is the embedded font file name in the resources that will be used to render text using this font table entry. Note that when setting the .efnt resource to be used by an entry, that entry has to exist in the resources – if it doesn't an error will occur.

The next two columns indicate what Background color (BCOLOR) and Foreground color (FCOLOR) will be used when rendering the text. The FCOLOR is the color of the actual character pixels, the BCOLOR is the color of the pixels surrounding the character. The values in the table are 16-bit RGB565 values – they are shown in the listing as if they were set using the RGB( ) function – which they can be.

The next four columns control the relative positioning of the characters when text is rendered with this font entry. The SPACEX column controls the spacing between characters of the font. A value of '0' will use the fixed width of the font to place the following character. A '-1' will use the "bounding box" character width for horizontal spacing. A non-zero, positive value will force that spacing character to character when fonts are oriented horizontally.

The SPACEY column works in the same way but affects vertical spacing when fonts are oriented vertically. (not current supported)

The ALIGN columns control the relative placement of the drawn text relative to the starting coordinate provided the DRAW.TEXT command – or the text alignment to the coordinates. The ALIGNH entry controls the horizontal alignment: a value of '0' justifies the text from the left, a value of '1' centers the text and a value of '2' justifies the text from the right. The ALIGNV entry controls the vertical alignment: a value of '0' justifies the text from the top, a value of '1' centers the text and a value of '2' justifies the text from the bottom.

The last two columns control the transparency of the rendered text. A transparent pixel is not drawn with the result that anything it is drawn on top of will 'show through'. The BTRANS column controls the character background pixels and the FTRANS column controls the foreground pixels. A value of '0' forces those pixels to be drawn, a value of '1' forces those pixels to not be drawn.

All of these font table entries may be accessed – read / written using system variables – specifying an index of the entry:

System Variable	Values	Description
@FONT.EFNT$[entry]	"resource.efnt"	Gets/Sets embedded font resource for entry – resource must exist to set
@FONT.BCOLOR[entry]	RB565 pixel color	Gets/Sets font background color for entry – use RGB( ) to set

System Variable	Values	Description
@FONT.FCOLOR[entry]	RB565 pixel color	Gets/Sets font foreground color for entry – use RGB( ) to set
@FONT.SPACEX[entry]	-1 = bounding box 0 = fixed width >0 = spacing	Gets/Sets font horizontal spacing
@FONT.SPACEY[entry]	-1 = bounding box 0 = fixed width >0 = spacing	Gets/Sets font vertical spacing (not currently supported)
@FONT.ALIGNH[entry]	0 = left justify 1 = center justify 2 = right justify	Gets/Sets font horizontal alignment
@FONT.ALIGNV[entry]	0 = top justify 1 = center justify 2 = bottom justify	Gets/Sets font vertical alignment
@FONT.BTRANS[entry]	0 = normal 1 = transparent	Gets/Sets font background transparency
@FONT.FTRANS[entry]	0 = normal 1 = transparent	Gets/Sets font foreground transparency

And Now Drawing the Text

So now we can get back to the DRAW.TEXT command. As with the other commands here's the command format:

DRAW.TEXT f, x, y, expr	
Renders the expression on the current drawing @SURFACE relative to x, y using the font table entry f values	F = font table entry number (0 – 31) x = justification x coordinate (0 – 319) y = justification y coordinate (0 – 240) expr = the number or string to draw

So let's try this out. There's already some default entries in the font table. What if we write a simple program that draws "Hello!" in the center of the screen:

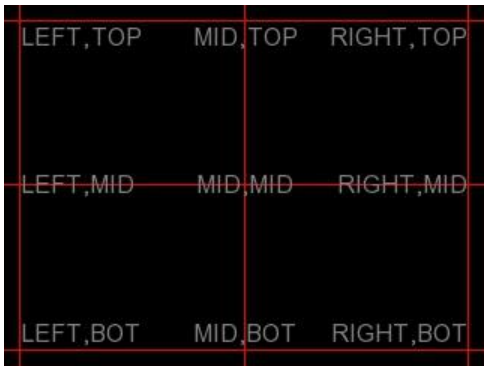
```
10 REM Draw text
20 @ANSI.ENABLE=0
30 DRAW.TEXT 0,160,120,"Hello!"
40 GOTO 40
```

Let's make the font red:

```
10 REM Draw red text
20 @ANSI.ENABLE=0
25 @FONT.FCOLOR[0]=RGB(255,0,0)
30 DRAW.TEXT 0,160,120,"Hello!"
40 GOTO 40
```

What do all of these alignment options do – there are nine combinations. Here's a program to show you how the @FONT.ALIGNH and @FONT.ALIGNV system variables control the relative text positioning. First we draw a grid using DRAW.LINE commands, then we DRAW.TEXT at the grid intersection points with the various font alignment options to show how they affect the text rendering:

```
5 REM Test font HALIGN and VALIGN
10 @ANSI.ENABLE=0
20 REM Draw grid
30 DRAW.LINE 10,0,10,239,RGB(255,0,0)
40 DRAW.LINE 160,0,160,239,RGB(255,0,0)
50 DRAW.LINE 309,0,309,239,RGB(255,0,0)
60 DRAW.LINE 0,10,319,10,RGB(255,0,0)
70 DRAW.LINE 0,120,319,120,RGB(255,0,0)
80 DRAW.LINE 0,229,319,229,RGB(255,0,0)
90 REM Draw aligned text
100 @FONT.HALIGN[0]=0:@FONT.VALIGN[0]=0:DRAW.TEXT 0,10,10,"LEFT,BOT"
110 @FONT.HALIGN[0]=1:@FONT.VALIGN[0]=0:DRAW.TEXT 0,160,10,"MID,BOT"
120 @FONT.HALIGN[0]=2:@FONT.VALIGN[0]=0:DRAW.TEXT 0,309,10,"RIGHT,BOT"
130 @FONT.HALIGN[0]=0:@FONT.VALIGN[0]=1:DRAW.TEXT 0,10,120,"LEFT,MID"
140 @FONT.HALIGN[0]=1:@FONT.VALIGN[0]=1:DRAW.TEXT 0,160,120,"MID,MID"
150 @FONT.HALIGN[0]=2:@FONT.VALIGN[0]=1:DRAW.TEXT 0,309,120,"RIGHT,MID"
160 @FONT.HALIGN[0]=0:@FONT.VALIGN[0]=2:DRAW.TEXT 0,10,229,"LEFT,TOP"
170 @FONT.HALIGN[0]=1:@FONT.VALIGN[0]=2:DRAW.TEXT 0,160,229,"MID,TOP"
180 @FONT.HALIGN[0]=2:@FONT.VALIGN[0]=2:DRAW.TEXT 0,309,229,"RIGHT,TOP"
190 GOTO 190
```



Drawing Images

Using all of the DRAWing command you can construct pretty line art displays. But how do we draw images – like photos or Photoshop generated graphics?

There is a DRAW.BITMAP command that will allow you to do this. While it is simple to use there are a few caveats:

1. The image to be drawn on the screen must be a Windows .BMP bitmap file.
2. The image must be resident in the display's memory by being a Resource.

To quickly try this command we'll use one of the built-in image resources. Use a RESOURCES.LIST command with a wildcard name pattern to list all of the image resources:

```
resources.list *.bmp
ButtonK.bmp  1,610 builtin
ButtonK2.bmp 2,050 builtin
ButtonK4.bmp 3,018 builtin
ButtonM.bmp  2,618 builtin
Ready
```

The names suggest that these are images of the buttons that the display uses for the Configuration Settings screen. They have to be 'built-in' so that they are always there – even when no other resources are loaded.

So let's draw one of the button images in the center of the screen. As before here's the command format from the Reference:

DRAW.BITMAP x, y, imageResourceName	
Renders the bitmap resource on the current drawing @SURFACE at x, y	x = image lower-left x coordinate (0 – 319) y = image lower-left y coordinate (0 – 240) imageResourceName = the string name of the loaded image resource to draw

Type the following commands – first let's clear the screen:

```
draw.fill 0,0,320,240,RGB(0,0,0)
```

This leave the Ready prompt and blinking cursor at the top of the screen – OK for now. Now let's draw the ButtonK4.bmp image at the center of the screen. Type the following command:

```
draw.bitmap 160,120,"ButtonK4.bmp"
```

Your screen should now look like:

Surprise! The image looks like the Configuration Settings screen keypad spacebar – without any colors.

Why isn't it shown in the center of the screen at 160, 120? This is because the DRAW.BITMAP coordinates refer to where the lower-left corner of the bitmap image will be drawn. The ButtonK4.bmp happens to be 88 pixels wide by 22 pixels tall. So we could center it by subtracting half of these values from the x and y coordinates. Let's try moving it - type the following command:

```
draw.bitmap 160-88/2,120-22/2,"ButtonK4.bmp"
```

Your screen should now look like:

Notice that it is centered now, and also that it was drawn on top of what was already there – like stacking photos. The effect of all of the DRAW commands is cumulative – each one builds upon the resulting image.

Rules for Drawing

1. DRAWing commands use x (horizontal) and y (vertical) coordinates to control where they affect the screen.
2. Graphic DRAWing commands specify the color to use with a 16-bit additive RGB color model – expressed with a signed integer value or using the RGB(red,green,blue) function.
3. The DRAW.POLYGON commands require arrays of the x and y coordinates of the polygon vertices. The arrays must be pre-DIMensioned and the coordinates loaded before the polygon can be drawn.
4. The DRAW.TEXT command uses embedded font file (.EFNT) resources to render the text on the screen. The style, color, alignment and transparency of the drawn text are controlled by referring to a configured entry in the FONTS table.
5. The DRAW.BITMAP commands render Windows .BMP image resources on the screen. The x and y coordinates refer to the placement of the lower-left corner of the image resource on the screen.
6. Drawing is cumulative – each successive DRAW command builds on the results of prior commands.

Making Things Move

So we know how to make static screens using the DRAW commands. How do we make something that moves?

Let's draw a simple old-style sonar screen – like the ones used on submarines. It consisted of a circle and a sweeping line that rotated from the center. We know how to clear the screen, draw the circle and line, but how do we

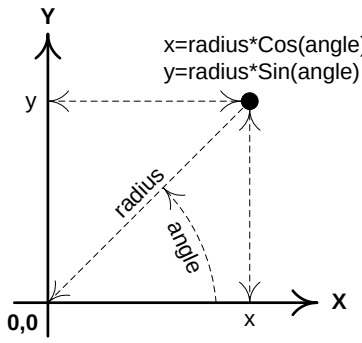
make the line rotate around the circle? We know the circle's center coordinate would be the line's starting point, but how to we dynamically compute the rotating line's end coordinate? For that we need to use some mathematics.

Warning – Mathematics

In mathematics, the trigonometric functions (also called circular functions) are functions of an angle. They are used to relate the angles of a triangle to the lengths of the sides of a triangle.

The most familiar trigonometric functions are the sine and cosine. In the context of the standard unit circle with radius 1, where a triangle is formed by a ray originating at the origin and making some angle with the x-axis, the sine of the angle gives the length of the y-component (rise) of the triangle and the cosine gives the length of the x-component (run). Trigonometric functions are commonly defined as ratios of two sides of a right triangle containing the angle, and can equivalently be defined as the lengths of various line segments from a unit circle.

Here's a drawing showing this relationship:



As we saw earlier in the section on functions, the ACS Color Basic has both SIN( ) and COS( ) functions. These trig functions take an angle argument and return the unit circle ratios – up scaled by 1024 since this Basic only provides integer math.

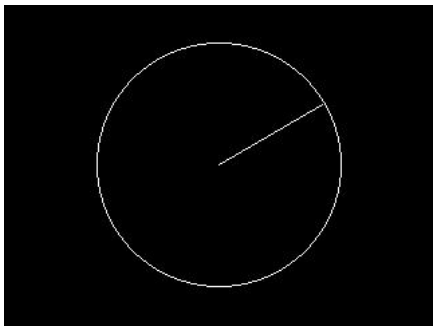
In order to perform the radius multiplication and subsequent down scaling by 1024 the MULDIV( ) function is used. This function multiplies the first two arguments as 32-bit integers and then divides by the third argument to return a 16-bit result.

We now have the pieces we need to draw our sweeping sonar screen. To rotate the line we un-draw it at its old angle then redraw it at the new angle as we sweep the angle through 360 degrees.

Here's the program:

```
10 REM Sonar Sweep
20 @ANSI.ENABLE=0:@BACKLIGHT=1
30 centerX = 160 : centerY = 120 : radius = 90
40 DRAW.FILL 0,0,320,240,RGB(0,0,0)
50 DRAW.CIRCLE centerX, centerY, radius, RGB(255,255,255)
60 FOR angle = 0 TO 359
70 lineX = MULDIV(radius-1, COS(angle), 1024)
80 lineY = MULDIV(radius-1, SIN(angle), 1024)
90 DRAW.LINE centerX, centerY, centerX + oldLineX, centerY + oldLineY, RGB(0,0,0)
100 DRAW.LINE centerX, centerY, centerX + lineX, centerY + lineY, RGB(255,255,255)
110 oldLineX = lineX : oldLineY = lineY
120 NEXT angle
130 GOTO 60
Ready
```

And here's what your display should look like – with the sweep line rotating counter-clockwise around the circle origin:

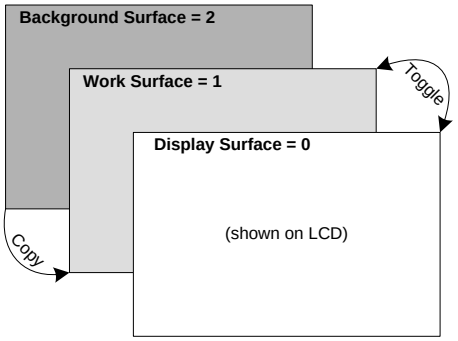


Moving Smarter

While this program works, there is a lot of flickering of the sweep line and we have to keep track of the line's old position so that we can un-draw it before redrawing it in its new position. There is a better way using an approach called ping-pong or double buffering.

With double buffering, drawing alternates between two different surfaces – one is shown while drawing on the other, then they are switched and the process repeats.

The Color LCD actually has three drawing surfaces to support this approach: Display, Work and Background:



The Background surface provides a content area that can be seldom drawn, and copied to the Work surface before additional drawing is done on top.

The Work surface is where most drawing is done before being swapped with the Display surface.

The Display surface is the one that is currently being shown on the LCD. This is the one that we have been drawing on up to now.

All of the DRAW commands operate on the current drawing surface which is set using a system variable - @SURFACE. The DRAW.TOGGLE command is used to swap the work and display surfaces – they aren't copied, the work surface becomes the display and the old display becomes the work surface.

In order to implement double buffering and avoid flickering as the display is updated we need to change our program to use the following sequence:

Double-Buffering Sequence

1. Switch to the Background draw surface.
2. Draw any required static background content.
3. Switch to the Work surface.
4. Copy in the content from the Background surface to the Work surface and draw any dynamic content on top of it.
5. Toggle the Work and Display surfaces.
6. Repeat from step 4.

Let's modify the sonar sweep program to use this double buffering approach.

Here's the DRAW.COPY command format from the reference:

DRAW.COPY src,sx,sy,dx,dy,w,h	
Copies the width x height bitmap from the src surface @ sx,sy on the current drawing @SURFACE at dx, dy	Src = source surface number (0, 1, 2) sx = source lower-left x coordinate (0 – 319) sy = source lower-left y coordinate (0 – 240) dx = destination lower-left x coordinate (0 – 319) dy = destination lower-left y coordinate (0 – 240) w = width of area to copy (1 – 320) h = height of area to copy (1 – 240)

First we'll select the background surface, clear it and draw in the circle – which is static – it doesn't change:

```
@SURFACE=2
DRAW.FILL 0,0,320,240,RGB(0,0,0)
DRAW.CIRCLE centerX, centerY, radius, RGB(255,255,255)
```

Next we'll select the work surface:

```
@SURFACE=1
```

Then we copy the background surface area encompassing the circle and draw the sweep line on it:

```
DRAW.COPY 2, leftX, leftY, leftX, leftY, width, height
lineX = MULDIV(radius-1, COS(angle), 1024)
lineY = MULDIV(radius-1, SIN(angle), 1024)
DRAW.LINE centerX, centerY, centerX + lineX, centerY + lineY, RGB(255,255,255)
```

Finally we toggle the work and display surfaces then rinse and repeat.

```
DRAW.TOGGLE
```

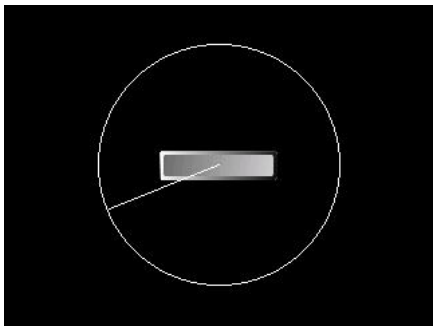
Here's the complete modified sonar sweep program that now uses the double buffering approach – run it and notice that the flickering is gone:

```
10 REM Sonar Sweep
20 @ANSI.ENABLE=0 : @BACKLIGHT=1
30 centerX = 160 : centerY = 120 : radius = 90
40 leftX=centerX-(radius+1) : leftY=centerY-(radius+1) : width=(radius+1)*2 : height=(radius+1)*2
50 @SURFACE=2
60 DRAW.FILL 0,0,320,240,RGB(0,0,0)
70 DRAW.CIRCLE centerX, centerY, radius, RGB(255,255,255)
80 @SURFACE=1
90 FOR angle = 0 TO 359
100 DRAW.COPY 2, leftX, leftY, leftX, leftY, width, height
110 lineX = MULDIV(radius-1, COS(angle), 1024)
120 lineY = MULDIV(radius-1, SIN(angle), 1024)
130 DRAW.LINE centerX, centerY, centerX + lineX, centerY + lineY, RGB(255,255,255)
140 DRAW.TOGGLE
150 NEXT angle
160 GOTO 90
```

Notice that the circle is only drawn once – in fact it could be a bitmap image. Add the ButtonK4.bmp image into the background screen:

```
75 draw.bitmap centerX-88/2,centerY-22/2,"ButtonK4.bmp"
```

Save and run it again. You should see the sweep line rotating on top of the button:



Changing Direction

The last example ran the animation at full speed – there was no delay between screen updates and the angle was incremented through an entire circle of 360 degrees in one degree steps.

What if you wanted to simulate the second hand of a clock? A few changes would be necessary; the motion should only occur once per second, the rotation would have to move clockwise instead of counter-clockwise, and since there are 60 seconds around the face of a clock the motion would have to advance:

$$\frac{360\ degrees}{60\ seconds} = 6\frac{degrees}{second}$$

Also – zero seconds is straight up to the 12 o'clock position – which is not the zero angle position but 90 degrees.

Let's start by tackling the non-zero angle for zero seconds and the clockwise motion. Remember from the earlier mathematics section that the angle advances counter-clockwise as the angle increases. If you change line 90 in the previous program to STEP the FOR/NEXT loop from 359 to 0 and run the program you will see that the motion is now in the clockwise direction. If you change the STEP value from -1 to -6 the motion is faster, but still in a clockwise direction.

So how can we translate the seconds to the required negative angle with the 90 degree offset? Let's start by offsetting the zero angle from the 360 degree position by 90 degrees – 360 + 90 = 450 degrees. From the previous equation and results we know that we have to subtract 6 degrees per second:

```
angle = (360 + 90) - (second * 6)
```

This equation yields angle = 450 when second = 0, and angle = 96 when second = 59. We need a way to limit the range of the computed angle to 0 – 359 degrees for use with the SIN( ) and COS( ) functions.

Enter the modulus operator: %. Integer division truncates (discards) the fractional part of the result. The modulus operator divides the value to its left by the value on its right and returns the remainder. When both values are equal or integer multiples, the remainder of the division is zero. This can be evaluated as:

x % y = (x – ((x / y) * y))

Try computing the modulus of 4 for various values:

0 % 4	= (0 – ((0/4) * 4))	= 0
1 % 4	= (1 – ((1/4) * 4))	= 1
2 % 4	= (2 – ((2/4) * 4))	= 2
3 % 4	= (3 – ((3/4) * 4))	= 3
4 % 4	= (4 – ((4/4) * 4))	= 0
5 % 4	= (5 – ((5/4) * 4))	= 1
6 % 4	= (6 – ((6/4) * 4))	= 2

You can see that the modulus ranges from zero when the arguments are equal to one less than the modulus. So taking the modulus 360 of the angle computation returns an angle between 0 and 359:

```
angle = ((360 + 90) - (second * 6) % 360)
```

If you now change lines 90 and 150 to count seconds from 0 to 59 and add line 95 to compute the angle you will see the motion being driven counter-clockwise in 6 degree increments as the seconds range from 0 to 59.

Rules for Making Things Move

1. To avoid flickering when moving graphics by DRAWing, use the double-buffering sequence.
2. You can compute the X and Y coordinates for DRAWing circular motion using the trig functions SIN( ) and COS( ) and scale the results using the MULDIV( ) function.
3. Incrementing angles rotate counter-clockwise, decrementing angles rotate clockwise.
4. The modulus operator % returns the remainder of the division of the two arguments.

Staging an Event

We could add a 1 second delay using a @TIMER system variable and increment the second variable from zero through fifty-nine every time that we read @TIMER is zero. There is another way that will allow our program to do other things instead of simply spinning in a loop waiting on a timer. Welcome to Events.

Events are changes in your program's execution that can happen in between each statement. The linear execution of your program's statements is interrupted to process the event and then execution resumes from where your program was interrupted. Events are associated with and triggered by some system variables and can occur as a result of hardware or software actions.

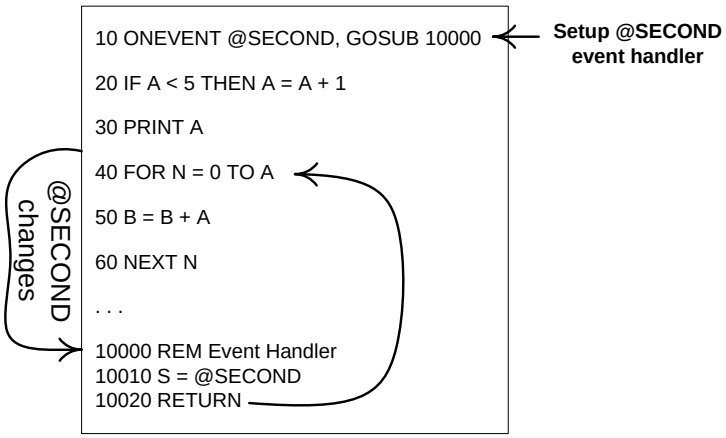
You control how system variable events are processed in your program by associating them with an event handler. The event handler is a subroutine you write that will be called when the event is signaled by changes in the associated system variable.

The event handler is configured or setup using the ACS Color Basic's ONEVENT command:

```
ONEVENT @systemvariable, GOSUB linenumber
```

This command records the handler subroutine line number in an event table for the specified system variable entry. Changes to system variables that cause events set a flag on their entry in the event table.

In between processing each program statement the Color LCD scans the event table looking for flagged entries. When a flagged entry is found the display performs the GOSUB to the recorded event handler line number. When the event handler subroutine returns, the display clears the flagged entry.


10 ONEVENT @SECOND, GOSUB 10000
Setup @SECOND event handler
20 IF A < 5 THEN A = A + 1
30 PRINT A
40 FOR N = 0 TO A
50 B = B + A
60 NEXT N
. . .
10000 REM Event Handler
10010 S = @SECOND
10020 RETURN
@SECOND changes

Events are prioritized – an executing event handler can only be interrupted by a higher priority event.

It is important to remember that all variables are shared between all parts of your program. If your program is performing some long calculation using a variable and you change that variable in an event handler your program may get confused or generate incorrect results since the event handler can potentially execute anywhere in your program after it is configured.

So let's add event processing to our second hand program. There is a system variable @SECOND that is updated once a second from the Color LCD Real Time Clock hardware. It signals an event when this happens. We will turn the program lines 95 – 160 into a @SECOND event handler.

Edit line 95 to change the second to the @SECOND system variable in the angle calculation:

```
95 angle = ((360 + 90) - @SECOND * 6) % 360
```

Change line 150 to a RETURN statement and remove line 160. Now add line 85 to configure the @SECOND event handler to call the new subroutine at line 95:

```
85 ONEVENT @SECOND,GOSUB 95
```

And, just to show that your program is capable of doing other things while updating the screen once a second replace line 90 with:

```
90 a = a + 1 : PRINT a : GOTO 90
```

Your program should now look like:

```
 10 REM Sonar Sweep
20 @ANSI.ENABLE=0:@BACKLIGHT=1
30 centerX = 160 : centerY = 120 : radius = 90
40 leftX = centerX-(radius+1) : leftY = centerY-(radius+1) : width = (radius+1)*2 : height = radius+1)*2
50 @SURFACE=2
60 DRAW.FILL 0,0,320,240,RGB(0,0,0)
70 DRAW.CIRCLE centerX, centerY, radius, RGB(255,255,255)
75 DRAW.BITMAP centerX-88/2,centerY-22/2,"ButtonK4.bmp"
80 @SURFACE=1
85 ONEVENT @SECOND,GOSUB 95
90 a = a + 1 : PRINT a : GOTO 90
95 angle = ((360 + 90) - @SECOND * 6) % 360
100 DRAW.COPY 2,leftX,leftY,leftX,leftY,width,height
110 lineX = MULDIV(radius-1, COS(angle), 1024)
120 lineY = MULDIV(radius-1, SIN(angle), 1024)
130 DRAW.LINE centerX, centerY, centerX + lineX, centerY + lineY, RGB(255,255,255)
140 DRAW.TOGGLE
150 RETURN
```

If you run this program, you will see the line rotating like a second hand – clockwise, 6 degrees every second. At the same time, your program is PRINTing an incrementing number.

Rules for Events

1. Events are interruptions to your program's normal flow of execution caused by hardware or software changes to system variables.
2. To process events you create an association between a system variable and a subroutine in your program using the ONEVENT command. The subroutine will be executed when the event is signaled by a change to the system variable. The event is cleared by the RETURN from the event.
3. You can disable further event handling for a system variable by executing an ONEVENT command with a line number of zero.
4. Variables are shared between your mainline program and any event handlers. Care should be exercised to ensure that inadvertent changes to variables in an event handler don't affect your main program logic.
5. Events are prioritized - only higher priority events able to interrupt an executing event handler.
6. Event handlers should be short so that lower priority events have a chance to occur.

Taking Control with the Screen Framework

By now you can probably see how you could use the DRAWing commands to construct some pretty fancy screens with animation.

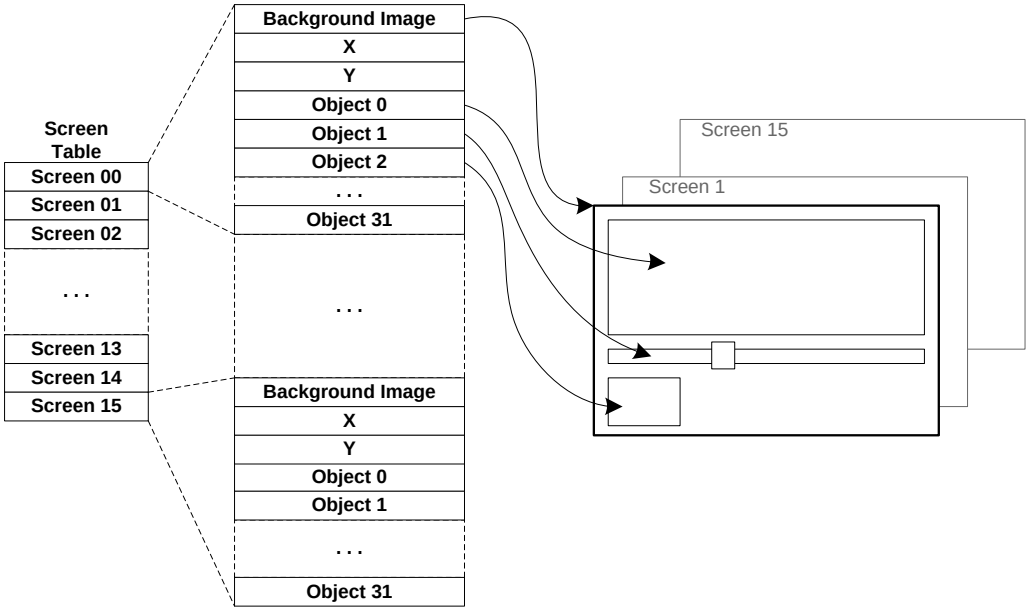
There is another method available to provide multiple screens, each with multiple controls – controls that provide a higher level of functionality and take care of drawing themselves and interacting with the user. This is accomplished using a built-in Screens Framework that ACS Color Basic has the commands and system variables to interact with.

There's a Table of Screens

Earlier we saw how embedded fonts and bitmap images were accessed using Resources and the Font table. The Screens Framework adds two more tables to the mix; a Screen table and a Scheme table.

The Screen table holds information about how to draw each Screen entry and what controls (Screen Objects) each Screen uses. The Screen table currently holds sixteen Screen entries, and each Screen entry currently holds up to thirty-two Screen Object entries.

Screen Object entries define what type of object (button, slider, gauge, label, etc.), how it is rendered (images, scheme, text, options), where it is positioned in relationship to the containing screen, what 'value' it has and other information used to interact with the user and running program. Here's a diagram:



ACS Color Basic has system variables to access the elements of the Screen table and commands to persist and 'navigate' the table – saving and loading the table and what screen entry to change to, push to or pop from. Screens are not stored fully rendered in memory but are 'constructed' (drawn) when navigated to.

Common Schemes Amongst Controls

The Schemes table holds information about how to draw and colorize images and display text.

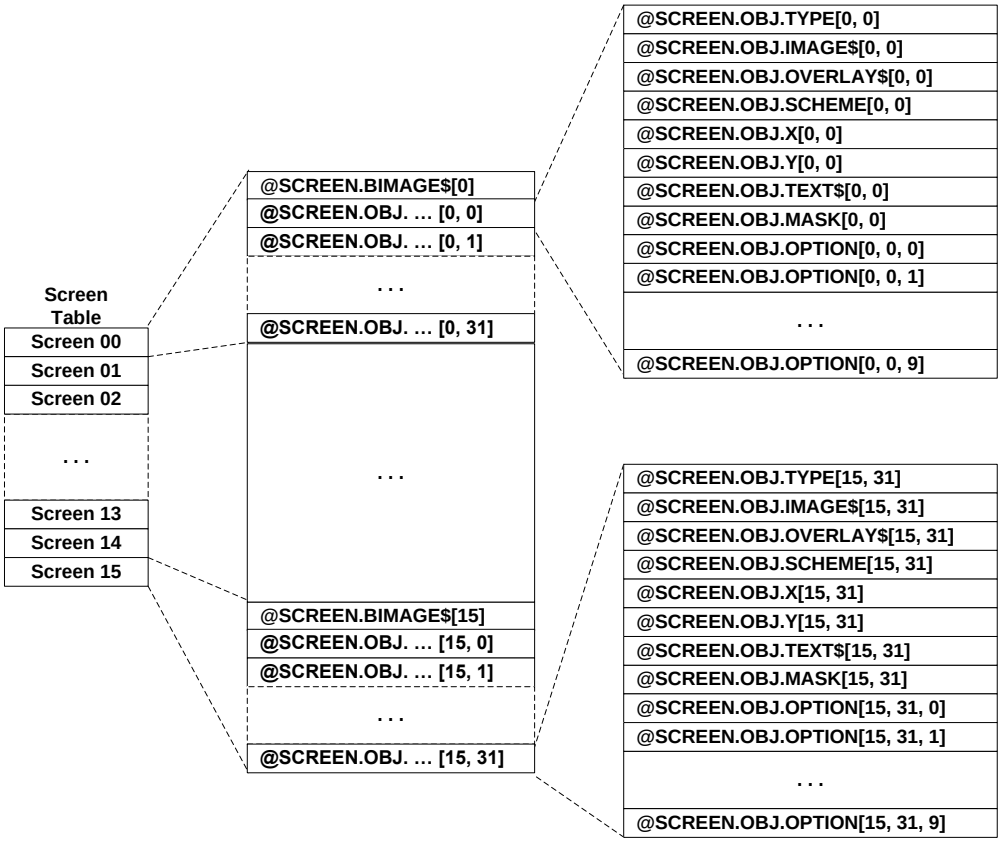
Screen Objects can reference Scheme table entries to control how they are drawn and colored as well as how any text that they display is rendered. Scheme table entries are usually used in pairs with the lower-numbered entry used to render an un-touched control and the higher-numbered entry used to render a control that is touched. In the previous section we drew a built-in keypad button bitmap that was drawn as grayscale – only shades of black to white were used. The Screens Framework's use of schemes allows these buttons and their text to be colorized – and the color to change as the buttons are pressed and released. This provides an easy way to accomplish a common look and feel for screen objects with the ability to easily change their appearance from one place. We'll examine schemes a little later on.

Controlling Screens and Objects

The Screen table elements are accessed using indexed system variables - the @SCREEN prefix is followed by one or more 'selectors' using the dot notation to select which entry's element is being accessed followed by the index to select the entry number in square brackets.

Accessing a Screen's object element requires a dual index to select the screen number then the object number. Finally, accessing a Screen Object's option element requires a triple index to select the screen number, object number and option number.

Here's a diagram showing the system variables and indices:



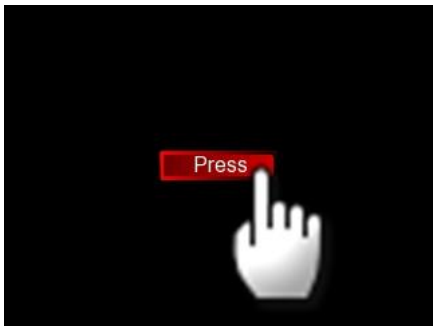
Touch Button Control

Let's try drawing a simple screen with no background image and a single button labeled 'Press'. Type in the following short program:

```
10 REM Button Demo
15 @ANSI.ENABLE=0 : REM Disable ANSI text
20 @SCREEN.OBJ.TYPE[0,0]=2 : REM Set screen 0 object 0 to Button type
25 @SCREEN.OBJ.SCHEME[0,0]=0 : REM Set button's scheme pair to 0,1
30 @SCREEN.OBJ.X[0,0]=116 : @SCREEN.OBJ.Y[0,0]=109 : REM Set button's location on screen
35 @SCREEN.OBJ.IMAGE$[0,0]="ButtonK4.bmp" : REM Set button's image
40 @SCREEN.OBJ.TEXT$[0,0]="Press" : REM Set button's text
45 SCREENS.CHANGETO 0 : REM Activate screen 0
999 GOTO 999
```

This program initializes the first screen object zero of the first screen table entry zero to position a button drawn using the built-in ButtonK4.bmp resource at the center of the screen. The gray button is labeled with the text 'Press' and is colorized using scheme table entry zero. The Screen Framework is then started by the navigation to this screen using the SCREENS.CHANGETO command.

Your display should look like the following – note how pressing the button changes its color shading automatically using the second entry of the scheme pair:



So how does your program 'know' when the user has pressed the button? There is a system variable that gets updated whenever a screen object changes state:

@SCREEN.OBJ.EVENT - This system variable reflects the last screen object event. There are currently three screen object events:

Value of @SCREEN.OBJ.EVENT	Indicates Screen Object Event
0	No event
1	Screen Object was touched
2	Screen Object value has changed
3	Screen Object was un-touched (released)

So let's change the program to watch this system variable and PRINT the event. To do this we'll use a new command – LIF, to control the program execution.

LIF is short for Long IF. If you remember the IF statement from *Controlling Program Execution* above, the command evaluates the following condition and IF it is True (non-zero) THEN it executes the command after the THEN otherwise it skips to the next line.

The LIF command works the same way except it executes all the commands on the line after the THEN when the condition evaluates to non-zero. This is useful when you want your program to do more than one command after testing a condition and avoid having to GOTO a new group of commands on another line to do so – it can make the program easier to write, follow and understand.

Add lines 50 – 65 below to the program and run it. These new lines test the value of the @SCREEN.OBJ.EVENT system variable and PRINT a message identifying the event. The event is then 'cleared' by setting it to zero and loops back to the top of the stack of LIF statements.

Try pressing and releasing the button and see what it printed:

```
10 REM Button Demo
15 @ANSI.ENABLE=0 : REM Disable ANSI text
20 @SCREEN.OBJ.TYPE[0,0]=2 : REM Set screen 0 object 0 type to Button
25 @SCREEN.OBJ.SCHEME[0,0]=0 : REM Set button's scheme pair to 0,1
30 @SCREEN.OBJ.X[0,0]=116 : @SCREEN.OBJ.Y[0,0]=109 : REM Set button's location on screen
35 @SCREEN.OBJ.IMAGE$[0,0]="ButtonK4.bmp" : REM Set button's image
40 @SCREEN.OBJ.TEXT$[0,0]="Press" : REM Set button's text
45 SCREENS.CHANGETO 0 : REM Activate screen 0
50 LIF @SCREEN.OBJ.EVENT = 1 THEN PRINT "Pressed" : @SCREEN.OBJ.EVENT = 0 : GOTO 50
55 LIF @SCREEN.OBJ.EVENT = 2 THEN PRINT "Value" : @SCREEN.OBJ.EVENT = 0 : GOTO 50
60 LIF @SCREEN.OBJ.EVENT = 3 THEN PRINT "Released" : @SCREEN.OBJ.EVENT = 0 : GOTO 50
65 GOTO 50
999 GOTO 999
run
Pressed
Value
Released
Value
. . .
Pressed
Value
Released
Value
```

Note the sequence of screen object events; Pressed, Value, Released, Value. A button only has two values; 0 and 1, but other controls like a slider can have several values that change between being pressed then released.

Multiple Objects

So how does your program handle multiple objects on a screen? There is another system variable that gets updated at the same time as @SCREEN.OBJ.EVENT with the number of the object that caused the event:

@SCREEN.OBJ.# - This read-only system variable reflects the screen object number of the last screen object event.

The previous screen framework example for a single button polled the @SCREEN.OBJ.EVENT using the multiple LIF statements in a loop. However, the @SCREEN.OBJ.EVENT is event capable and, in an associated event handler, you can use the @SCREEN.OBJ.# system variable to identify what object the event is being generated from.

To simplify this processing we introduce a new ON command. The ON command provides the ability to change the program's execution using the value of an expression in a single statement instead of testing for each condition with multiple IF or LIF statements. It can make a program smaller and easier to read and understand.

The ON command is followed by the expression to evaluate, then the execution directive which can be either GOTO or GOSUB, and then a list of line numbers for each value of the expression. The destination line number is selected from the list by the value of the expression.

```
ON Expr, GOTO lineIfExpr=0, lineIfExpr=1, … , lineIfExpr=n

ON Expr, GOSUB lineIfExpr=0, lineIfExpr=1, … , lineIfExpr=n
```

If the expression evaluates to zero, the first line number in the list is used for the GOTO / GOSUB, an expression value of one selects the next line number, two the next and so on.

If the expression evaluates to a negative value, or to a value beyond the number of line numbers in the list, execution continues with the program statement following the ON command. If the selected line number in the list is zero, execution continues with the program statement following the ON command.

So let's add an event handler for the @SCREEN.OBJ.EVENT. We'll use the ON command to help process the event. We'll add a label object to the screen. The event handler will update the label object's .TEXT$ to display the button's last state; Pressed or Released. Here's the revised code:

```
10 REM Button Demo
15 @ANSI.ENABLE=0 : REM Disable ANSI text
20 @SCREEN.OBJ.TYPE[0,0]=2 : REM Set screen 0 object 0 to Button
25 @SCREEN.OBJ.SCHEME[0,0]=0 : REM Set button's scheme pair to 0,1
30 @SCREEN.OBJ.X[0,0]=116 : @SCREEN.OBJ.Y[0,0]=109 : REM Set button's location on screen
35 @SCREEN.OBJ.IMAGE$[0,0]="ButtonK4.bmp" : REM Set button's image
40 @SCREEN.OBJ.TEXT$[0,0]="Prog" : REM Set button's text
45 @SCREEN.OBJ.TYPE[0,1]=6 : REM set screen 0 object 1 to Label
50 @SCREEN.OBJ.SCHEME[0,1]=0 : REM set label's scheme pair to 0,1
55 @SCREEN.OBJ.X[0,1]=160 : @SCREEN.OBJ.Y[0,1]=151 : REM set label's location on screen
60 @SCREEN.OBJ.OPTION[0,1,0]=88 : REM override label width
65 ONEVENT @SCREEN.OBJ.EVENT,GOSUB 1000
70 SCREENS.CHANGETO 0 : REM activate screen 0
75 GOTO 75
1000 REM screen object event handler
1005 IF @SCREEN.OBJ.#=0 THEN ON @SCREEN.OBJ.EVENT-1, GOTO 1015,0,1020
1010 RETURN
1015 @SCREEN.OBJ.TEXT$[0,1]="Pressed" : RETURN
1020 @SCREEN.OBJ.TEXT$[0,1]="Released" : RETURN
```

And now, when we run it and press the button the label above the button is updated to show the button's last state:

App started

Button pressed

Button released

Diving Into the Screen Framework

So how does this Screen Framework actually work? It uses messages and the multiple drawing surfaces system to perform its magic.

When the screen framework is started by the initial SCREENS.CHANGETO command, the screen is constructed using the following sequence of steps:

1) If there is a screen background image .BMP resource specified it is drawn onto the background surface, if not the background surface is filled with black.
2) Each screen object is sent a message to render their background information.
3) The background surface is then copied to the work surface.
4) Each screen object is sent a message to render their working information.
5) The work and display surfaces are then toggled so that what was the working surface is now the display surface and is being shown on the LCD.
6) Each screen object is sent a message to render any additional dynamic content on the displayed surface.

After the screen is constructed, a construction event is signaled via the @SCREEN.EVENT system variable, with the @SCREEN.# variable identifying what screen number the event is being generated from. This allows the Basic program to initialize any variables, start timers or perform other functions specific to or required by the activating screen.

If a new screen is navigated to by a .CHANGETO or .PUSH or .POP command while a current screen is being displayed, a destruction event is signaled via the @SCREEN.EVENT variable and then the new screen is constructed. This allows the Basic program to stop timers or disable other functions that were in use by the previous screen.

When the user touches the screen a message containing the touch state; press, move or release, along with the screen coordinates is sent to each object on the screen. Each object determines whether it is affected by the touch event, possibly updating its state and updating its appearance on the screen. If the object determines is has been touched or its .VALUE has changed an event is signaled via the @SCREEN.OBJ.EVENT system variable, with the @SCREEN.OBJ.# variable identifying what screen object number the event is being generated from.

The Basic program can DRAW on the display surface after the screen constructed event has occurred. Any drawing done on the display surface between the SCREEN navigation command and the screen constructed event would appear to be drawn on the work surface after step 3 above occurs. Double buffer or ping-pong drawing should not be performed as it will interfere with the Screen Framework's operation.

Screen object's .VALUEs can be changed by the program to cause the object to change its appearance on the screen. These changes should be made after the object's containing screen has been constructed as determined by the construction event. Changes before the occurrence of the screen construction event may be overwritten or discarded until the screen (and its objects) have been constructed.

Using the screen framework and controls can simplify a Color Basic graphic application as the screens and objects manage the drawing surfaces and render themselves in response to system variable changes and user touch interaction.

Rules for the Screen Framework

1. The Screen Framework is comprised of multiple system variable tables that specify what objects (controls) are located where on each screen and how they are displayed.
2. The Screen Framework is started by the first SCREENS.CHANGETO or SCREENS.PUSHTO command.
3. Screens are not stored fully rendered but are constructed (drawn) when navigated to.
4. Screens and screen objects signal changes by using events.
5. Screens can be DRAWn on after they are constructed but not by using the double-buffering technique.

to be continued…